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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. I.

No. I.—JANUARY, 1894.

ORIGINAL ARTICLES.

I.—Coral in the "Dolomites" of South Tyrol.

By Miss Maria M. Ogilvie, D.Sc. (Lond.).

(Part I.)

I.—General Character of the Scenery—The Interpretation of the Mid-Triassic Succession given by the "Coral Reef Theory."

At the meeting of the British Association in Nottingham, in August of last year, a joint discussion on "Coral Reefs" was held by the sections of Zoology and Geology.[1] Prof. Sollas, in opening the discussion, referred to the "Dolomites of South Tyrol" as a country affording brilliant examples of Fossil Coral Reefs. He demonstrated this by sections taken from the well-known work of Mojsisovics, and showed several photographs of some of the more imposing dolomite mountains—Schlern, Langkofl, and Sella—which had been explained as reefs of Triassic age. In the course of the discussion, Dr. Hickson said he believed there were no corals in these so-called fossil reefs. Dr. Rothpletz corrected this statement, saying briefly that there were corals in the dolomite and limestone rock, along with other groups of marine animals, but that many of the sections shown by Prof. Sollas were incorrect. Prof. Bonney emphasized the ample evidence of Coral life in many parts of the district which he had visited.

I may be pardoned for recapitulating the part of the discussion bearing on South Tyrol, as I wish to state here the conclusions which I have formed with regard to Coral Reefs from my geological work in that neighbourhood. So far as South Tyrol gives countenance to one theory of the growth of Coral Reefs or the other, it supports in the main Murray's theory and not Darwin's. It displays striking analogies with the observations of recent reefs made by Agassiz in the West Indian and Caribbean Seas, by Dr. Guppy in the Solomon Islands, by Dr. Murray on the Barrier Reef of Tahiti and the Great Chagos Bank, by Prof. Semper in the Pelew Islands, by Dr. Rein, Dr. Sydney Hickson, and others. Some of the special points of correspondence may be indicated at once. Volcanic eminences formed submarine platforms in the Triassic ocean of South Tyrol, on which Corals built in Wengen and Cassian time. One special

[1] An account of the discussion is given in "Nature," October 12th, 1893.

ridge, south of Gröden and Enneberg, apparently the outermost at that time, formed the basis for a more or less continuous barrier-like chain of reefs, behind which (*i.e.* to the north) deposits collected of a different nature from the ordinary marine deposit of the Southern Ocean. These deposits include in their uppermost horizons the wonderful Cassian fauna of Enneberg, and probably the faunal conditions of the Cassian-Enneberg sea of Triassic South Tyrol may be justly compared with these of the Caribbean Sea at the present day. At a later Triassic period, in Raibl time, banks of reef-coral were formed on raised beds of ordinary submarine deposit. On the other hand there is every reason to suppose that in the particular periods of Trias in South Tyrol pre-eminent for the growth of Coral Reefs, the sea-floor was undergoing extensive movements of subsidence, subject to oscillation in the near vicinity of volcanic action. In the St. Cassian area, between the two main periods of Coral growth an interval of quiet subsidence intervened, marked in many places by the cessation of Coral growth and the accumulation of a marine deposit enclosing calcareous algæ.[1]

The Wengen and Cassian Coral Reefs of Gröden, Enneberg, and Upper Fassa have remained, with but rare exceptions, limestone. The actual thickness attained by the individual lenticular Coral Reefs or the Coral Banks is in no case very great, seldom more than 150 feet, and usually much less. The steep slope of the outer chain of reefs was mainly composed of volcanic rock with interbedded reef-limestones. As negative evidence it may be mentioned that the so-called "Dolomite Reefs," viz. the thick dolomite massifs of Schlern, Sella, etc., have originated as marine deposits and not Coral Reefs, probably calcareous in the greater part of their thickness, and only in their upper horizons originally dolomitic. The reef-like appearance assumed by these dolomite massifs is in small measure due to the variation in the character of contemporaneous Triassic deposits, but it is chiefly the result of the movements of the rocks in Tertiary time.

I have selected for the sketch-map[2] a long stretch of country between the Eisack Valley, with the Brenner railway on the west, and the Ampezzo Valley on the east. The map displays at a glance the characteristic physical features. Precipitous rocks, generally of a creamy or rose-tinted crystalline dolomite, rise to great heights above green swelling passes and grazing land, or sometimes descend at once into deep gorge-like valleys. The artistic sense scarcely knows which to love most—the romantic region of fir-wood and stream and human habitation, or the wild solitariness of the rocks beyond. Villages are perched midway between mountain and ravine, looking in some of the narrower valleys as if a push would throw them into the gap below. The simple Ladinian folk wander

[1] Mr. George Murray made the following observation in the Antilles:—"Many coralline sea-weeds living at greater depths than the Corals grow with a stout incrustation of carbonate of lime, and thus form great masses which seem to nearly rival the true Coral Reefs in bulk" ("Nature Notes," February, 1891).

[2] The Map will appear in the February Number with Part II. of this paper.

summer and winter among the rough winding paths and dilapidated huts, content to lead their cows and mow their hay. In the wider valleys the sun ripens hearty crops twice a year, and life flows on pleasantly, after a lazy Italian fashion. The barrenness of the dolomite mountain is such that even chamois rarely frequent their clefts and terraced table-lands; snow caps most of them during nine months out of the twelve, and is perpetual on the highest summits.

With the exception of a few scattered remnants of Jurassic and Cretaceous rock, the geological age of the deposits exposed throughout this country is Triassic. We are concerned with the history of Triassic deposit in South Tyrol, in the midst of which, we are told, there came a long epoch of Coral growth and reef-building. If this be true, the data of the geologist have a keen interest both for the geographer and the zoologist, whose duty it is to compare these fossil Coral Reefs with reefs now growing, and find corroboration or the reverse for the various theories which have been advanced regarding the growth of recent Coral Reefs. The chief data which geology determines, are the exact nature of the sedimentary rocks, the order in which they succeed one another, the fossil remains which they contain, and any particulars regarding the manner of occurrence of the fossils. That seems a simple enough commission, and yet in practice it is often very hard to execute, no part of it more hard in the Alps than that of determining the order in which the rocks succeed one another. For the sediments which were deposited by the great basins of water in Triassic time have since been folded and twisted and raised into entirely new positions in relation to one another. So that a rock which was once below is now alongside or even above its neighbour—or its fossils have been destroyed, or a volcanic invasion has taken place; in fact, endless accidents may have happened since Triassic time, and it requires much time and patience to unravel the mysteries introduced into a once simple succession. In a word, to be a good ancient geographer of the Trias, one must first be a wary stratigraphist.

We shall begin by quoting the succession of Triassic rocks in South Tyrol and the interpretation of it given by Mojsisovics[1]:—

RHÆTIC BEDS.

Dachstein dolomite.
Raibl marls, sandstones, dolomite.

CORAL REEFS OF	Cassian Dolomite	thinning into contemp. deposits of	Cassian marls and limestones.
	Wengen ,,		Wengen shales and volcanic ash.
	Buchenstein ,,		Buchenstein limestones and ashy rocks.

Muschelkalk (Alpine) limestone or dolomite.
Werfen shales and thin bedded sandy limestones.

PERMIAN ROCK.

The actual part which these rocks take in the landscape may be briefly described. The so-called "Coral Reefs" rise as sheer precipices 2000–3000 feet high, or dwindle to nothing. The gaunt form of their cliffs is unbroken by familiar planes of bedding. Raibl marls draw themselves as a narrow band above them, and

[1] E. Mojsisovics v. Mojsvár, "Die Dolomit-Riffe von Süd Tirol und Venetien," Wien, 1879.

Dachstein dolomite, well stratified and often of very great thickness, builds the highest terraces and precipices. The Cassian, Wengen and Buchenstein sedimentary beds are exposed on the passes between "reefs," on their lower slopes, and over the large meadows which the people of the place call "Alpen." The Muschelkalk and Werfen series form the bed of the streams in the rapidly descending mountain valleys. It may be at once remarked that typical fossils have been found in all members of the succession. In the "reef-dolomite" fossil remains are extremely poor and scanty; plant algæ are got even more often than Corals, Gasteropods, or Bivalves. *Ammonites* occur, but usually in too meagre a state of preservation to be of much service in identifying the age of the rock.

Besides the layers of volcanic ash and lava which are interbedded with the Wengen beds, there is every here and there a massive looking volcanic rock, Augite Porphyry, which surprises the eye by its strong contrast to the dolomitic rocks. Everyone knows that Coral growth in our present seas is particularly luxuriant where volcanic action is occasionally felt, and this seems a strong argument in favour of the view which explains these Triassic dolomites as Coral limestones, largely magnesic, which were built in a volcanic sea of the far-away Trias period. The later conversion of such magnesic limestone reefs into pure dolomite also finds its parallel in recent reefs. So that the "Coral Reef Theory of the Dolomites" presents, as a theory, no problem which is not in harmony with recognized facts, unless we except the enormous thickness attained by the reefs, and the occurrence on their upper surfaces and slopes of an appearance which Mojsisovics observed and called "overcast bedding."

A geological theory, however, stands by virtue, not of its probability argued from Nature's Present, but its absolute fitness to the facts observed in Nature's Past. And, when the same facts may bear two or even more explanations, the theory which is to stand in Science must fight for its position as the fittest survivor! We have to ask ourselves if the Coral Reef theory offers the only probable explanation of the dolomite cliffs. The mere occurrence of a couple of thousand feet of limestone or dolomite is part of the A B C of Geology, when taken as the accumulation of ordinary marine deposit. Dachstein dolomite is such a rock, and it still carries testimony of its origin in the numerous *Megalodon* bivalves and other fossils which it contains. Again, a considerable amount of variation in the thickness of any marine deposit might be expected, especially where volcanic eruption had previously disturbed the sea-floor and produced all degrees of inequalities by heaping up its ashy flows in some parts more than in others. But the special difficulty said to meet us in the case of the Cassian and Wengen dolomite of South Tyrol is, that rocks of 2000 feet in thickness rise quite suddenly from the midst of sedimentary earthy beds, and show certain curious appearances in relation to them. The dolomite rock seems to dovetail at its extremities into the marly and ashy beds,

giving rise to strange anomalies in the geological succession, which could only be explained by regarding every case as one of contemporaneous deposition of different classes of rock very close to one another, so-called "Heteropism." Such difficulties can only be solved by stratigraphy, and to that we must turn for proof of the data on which the Coral Reef theory rests.

For the sake of clearness in writing, we prefer to use, instead of the triple term applied to the reef-dolomite by Mojsisovics, the single name given by von Richthofen, of "Schlern dolomite,"[1] from its characteristic occurrence at Schlern Mountain, south of the Gröden Valley.

II.—Normal Marine Formations of Mid-Trias in the Southern Alps—Submarine Volcanic Action in Upper Fassa and the neighbouring districts—The "Dolomite Reefs" of Enneberg and Ampezzo correspond to part of the Normal Marine Deposits of the South.

Whereas during the Wengen and Cassian period, volcanic activity was rife in the northern part of the area covered by the sketch-map, an accumulation of marine deposit apparently went on during a steady subsidence of the sea-floor over the southern areas. Great thicknesses of limestone and dolomite represent this period in the southern part of the South Tyrol, and in the Venetian and Bergamasker Alps. These are known in different localities as Esino limestone, Marmolata limestone, Schlern dolomite. The fauna is liable to great variation, but includes for the most part a typical assemblage of Mollusca, Echinoderms, Corals, and Gyroporellas (sea algæ). This we may regard as the *normal* oceanic formation of the mid-Triassic period in the Southern Alps.

In the Upper Fassa and Gröden, Enneberg and Ampezzo districts, intermittent outpourings of volcanic matter took place from one or more submarine craters, associated perhaps with the proximity of this part of the sea to pre-Triassic land of Palæozoic and crystalline rocks, and with Triassic earth-movement. Be that as it may, the southern rocks of Schlern dolomite, Marmolata and Esino limestones, were clearly collected in deeper waters than the contemporaneous deposits immediately to the north. This is nowhere better seen than at Schlern Mountain, where the deep-sea deposits on the south side of Schlern pass rapidly into the volcanic lavas and shallow-water deposits on the Seisser Alpe to the north. According to von Richthofen's original interpretation of this district, the upper part of the "Schlern dolomite" of Schlern was younger than any of the sedimentary beds on the Seisser Alpe, a stratigraphical fact of general import, which many geologists have since verified at this point.

Following an irregular line eastward and south-eastward, we may trace the same occurrence of stratigraphical facies. It takes place most suddenly where the Wengen lavas are thickest, *i.e.* in Upper Fassa. The dovetailing of the dolomitic and calcareous

[1] Schlern Dolomite. *Vide* von Richthofen, "Geognostische Beschreibung der Umgegend von Predazzo, St. Cassian und der Seisser Alpe," 1860.

strata with volcanic and marly beds which takes place along this volcanic zone is therefore perfectly comprehensible in the light of every-day facts of deposition. There is no need to call the massifs of Schlern, Rosengarten, Latemar, Marmolata, etc., "Coral Reefs," merely because a thin line of heteropic division may be traced between these two areas of Triassic rock in South Tyrol. Moreover, the local recurrence of volcanic activity during a prolonged period would explain the continuance of different conditions in adjoining districts. While a simple interpretation such as the above would explain one of the main features of Triassic geology in South Tyrol, it may be objected that it would not apply within the volcanic district itself, for it is in Enneberg and Gröden, more than in any other part of South Tyrol, that the curious suddenness of the "Reefs" strikes the eye.

As I have said in a previous paper,[1] every member of the Triassic succession in South Tyrol presents variations in its thickness when followed from place to place. More especially is this true of the beds from Muschelkalk to Dachstein Dolomite. The names Cassian, Wengen, and Buchenstein mark different horizons in a series of volcanic lavas, ashy and tufaceous marls, calcareous marls and limestones, which may, lithologically considered, be united as one series. This series represents, no doubt, the upward continuation of Alpine Muschelkalk much as the Partnach beds do in North Tyrol.[2] Zones may be followed in which certain fossil genera predominate in the number of individuals and species; but the palæontological facts give us not so much a clear succession of types as an index to the facial conditions which influenced the life of the period.

For instance, *Halobia Lommeli* is a fossil bivalve which is common in tufaceous beds both of Buchenstein and Wengen age; but in Buchenstein limestones the general character of the fauna is more like that of the Muschelkalk, whereas limestones of the Wengen age contain the remains of Corals and Echinoids like those in the next following Cassian deposits. Again, *Posidonomya Wengensis* is another bivalve which gradually outnumbers *Halobia Lommeli* in tufaceous beds belonging to upper horizons of Wengen beds, and it is a fossil which again and again reappears in Cassian time always associated with the same lithological character of deposit, and shewing but slight varietal changes in its outward form. It is one of these persistent types which saw the birth and destruction of innumerable shoals of less fortunate species and genera characteristic of the Cassian limestones.

In the district of Upper Fassa there are true Augite Porphyry lavas of Lower Wengen age, which appear more or less interstratified with grits and tuffs. In the Enneberg districts, *i.e.* north of Upper Fassa, the lavas pass into black earthy tuffs and crumbling grits, in which the fauna is very limited and fragments

[1] "Contributions to the Geology of the Wengen and Cassian Strata in South Tyrol," by M. M. Ogilvie," Quart. Journ. Geol. Soc., vol. xlix. p. 47, February, 1893.

[2] "Ueber die Entwicklung u. Verbreitung der Partnachschichten," etc., by Dr. T. Skuphos, Jahrb. der k.k. Geol. Reichsanstalt, 1893, Bd. 43, p. 178.

of plants are of frequent occurrence. Mojsisovics has proved that these invasions came from a submarine volcano, probably in Upper Fassa, which "lay on the edge of the district of greater subsidence" to the south. "In Triassic time, as we are taught by the history of the Triassic reef masses, a certain protraction took place in the subsidence going on at the edge of the insular core of older rocks to the north as compared with a more rapid subsidence of the outer regions" (Mojsisovics, "Die Dolomit-Riffe von Süd-Tirol und Venetien," p. 525). We may naturally suppose that Augite Porphyry lavas formed irregular ridges on the disturbed sea-floor, more especially near the eruptive centre. From the beginning of this period we trace a marked difference in the deposits and fossil remains of the non-volcanic and volcanic areas respectively south and north of the Upper Fassa ridge, and even considerable variation within the shallow volcanic sea itself. A representation of the sea-floor in this period is given in Diagram I.

Corals found abundant "coigns of vantage" and were aided by Echinodermata to form communities of organic life, often prevented from farther growth by new volcanic invasions, but ever and anon settling down afresh. The remains of these form the "Cipit blocks" and "Cipit limestones," which were first observed by von Richthofen amid Cassian marls on the slopes below Schlern. Mojsisovics recognized similar limestones appearing intermittently over the whole area eastward. I have given special attention to the relations of these limestones with the contemporaneous rocks, and shall at once describe the more interesting results.

They, and not the mountains of Schlern dolomite, deserve the name of "Coral Reefs" in South Tyrol. They never attain any great thickness; generally in highly volcanic periods they formed mere isolated blocks composed of colonies of Corals and Echinoderms, and closely wedged amongst tuffy marls. In less volcanic periods continuous beds spread over a larger area—sometimes suddenly swelling out in lenticular fashion, sometimes perceptibly thinning into deposits full of other classes of animals. Stratigraphically considered, they occur as the equivalents of Cassian and Wengen strata, and in a less degree of Schlern dolomite and Raibl strata, and they follow certain fairly definite laws of distribution. Diagrams I. II. and III. represent successive stages in the history of the heteropic deposition in South Tyrol during this part of the Triassic era; Diagram IV. represents approximately the occurrence of Cipit Limestones in the contemporaneous series of rocks. In the Upper Fassa and Schlern districts the Cipit or reef-limestones occur at various horizons in the midst of volcanic earthy Wengen beds, or associated with sedimentary beds containing *Halobia Lommeli*, *Posidonomya Wengensis*, etc. They continue upwards in that district to the base of the Schlern dolomite, but are associated, north of the Schlern Mountain, in their higher horizons with characteristic Cassian fossils.

In Gröden Joch and in Enneberg, the Cipit Limestones do not make their appearance until the Wengen beds are giving place to

Cassian. The block-like structure observed in the Schlern and Fassa district becomes less prominent in Enneberg, and we are rather presented with thick unevenly bedded limestones full of *Cidaris* spines and Thecosmilian Corals, more rarely with Brachiopods and small Mollusca.

These are immediately succeeded in Enneberg by the great mass of thinly-bedded typical Cassian beds. The latter, therefore, correspond on Stuores meadows to the upper part of the Cipit Limestones of the Seisser Alpe and Sella Joch, and to some part of the lower horizons of Schlern dolomite at Schlern, and at Sella and Sasso Pitschi. Sometimes the outpouring of volcanic material, which was constantly recurring in Upper Fassa, caused the sudden disappearance of the rich fauna of Enneberg. During the short periods of disturbed deposition which then ensued, Echinodermata, even more than Corals, peopled the seas.

Thin beds of Limestone were thus formed at intervals amid tufaceous sediments of Cassian age, but the main thickness of Cassian beds in Enneberg is composed of soft marls and limestones full of the remains of Brachiopods, Mollusca, and many species of non-reef-building Corals. This fauna lived, I believe, in an inner area of quiet water, secluded from the Southern Ocean by the Cipit reefs and volcanic rocks, some deeper channels being left free.

Whereas the Wengen and Cassian beds retain their tufaceous character, in greater or less degree, throughout the whole district of Enneberg, they show it much less in the corresponding deposits of Ampezzo. Fine, unfossiliferous shales and clays take the place of the tufaceous grits, and although Corals and Sponges occur in hard limestones of Cassian age, they are seldom in sufficient magnitude to form any appreciable reef-like thickening. The same is true of the northern or "Abtey" part of Enneberg, and of the deposits of Seeland Valley and Misurina, north-east of Ampezzo. Hence Cipit-Limestone building flourished most in the volcanic areas of Gröden and Upper Fassa. I observed, however, in the higher horizons of Cassian strata at Ampezzo thick, reef-life extensions of Limestones, mostly one mass of the spines of *Cidaris Hausmanni*. They form bands of rock between softer beds, and are present as well in the undisturbed series below the Schlern dolomite of Lagazuoi as in the disturbed succession near the small Lago Majorera to the east (close to the Falzarego road). The stratigraphical facts afford evidence that the Cassian marls are both in Enneberg and Ampezzo succeeded by a dolomitic rock, and never conformably by fossiliferous Raibl sandstones and marls. As might be expected from the occurrence of an upper palæontological zone of Cassian beds in the Ampezzo districts (Upper Cassian—*vide* M. M. Ogilvie, *loc. cit.* pp. 46, 47), the dolomite rock which succeeds Cassian strata did not everywhere begin to be deposited at the same time.

In the south-west, where a true marine formation had been continued throughout the Wengen and Cassian period, the deposit has only sometimes a stratified appearance. Mojsisovics has ascribed

some parts of the Latemar and the mountains still further west to a lagoon formation; but he describes a large, originally continuous, dolomite mass, "with the Schlern for the most northerly, and the Piz, near Sagron, for the most southerly point," as an immense Reef. The Marmolata Mountain and the Mount Alto de Pelsa "are two important continuations of this mass, jutting out in peninsular fashion into the eastern district" (*vide* "Horizontal Extension of the Dolomite Reefs in Lower Wengen Time," Mojsisovics, *loc. cit.* p. 482). In the case of Schlern, where the upper part of this rock is stratified and the lower apparently unstratified, we are told that the lower part is Coral Reef, the upper part is lagoon deposit. But in many portions of this western "Reef," it has been proved that the remains of algæ and mollusca form the important part of the deposit. Whether stratified or unstratified, there is no reason why the Schlern dolomite of this Western "Reef" should not be regarded throughout simply as a lagoon and marine formation. In no single case has it been proved that reef-coral continuously built vertical cliffs of Coral rock during the mid-Triassic period of subsidence represented by Esino limestone, Schlern dolomite, etc.

This typical calcareous or dolomitic rock in the south-west of the district succeeds in the northern and eastern areas, in greater or smaller thickness, the volcanic series and the marls and limestones of Wengen and Cassian age, gradually succeeding the upper horizons of the series towards Enneberg and Ampezzo. The so-called Schlern dolomite "Reefs" of these areas can never be said to be contemporaneous with the marls at their own base unless, as in the case of the Schlern Mountain, denudation has allowed the rock to remain standing over such an extensive area that the dolomite of one portion is contemporaneous with the marls underlying the dolomite further north. To express the same fact somewhat differently, the fossiliferous marls and limestones of Enneberg were not laid down against Coral cliffs, but form a deposit belonging to a definite palæontological horizon, and succeeded by a dolomitic or calcareous rock of marine or lagoon formation. For this dolomitic or calcareous rock between the fossiliferous deposits of ascertained Cassian and Raibl age in the Enneberg and Gröden district, it is best to preserve the name of Schlern dolomite,[1] as no sufficient faunal distinction has yet been carried out between different horizons of the said dolomitic rock in the south-western area of its complete development.

I must refer the reader to my sections and maps already published for further proofs of the conformable succession of Schlern dolomite on the Cassian beds in Enneberg. I shall now recapitulate the main conclusions which may, I think, be drawn from what I have already stated:—

1. The frequent occurrence of Coral remains in the "dolomite" country is a fact, often repeated, but somewhat vaguely applied, bearing with it no evidence whatever of the Coralline origin of the "dolomites" themselves.

[1] Schlern dolomite: In using the expression "dolomitic or calcareous rock" I wish to take nothing for granted as regards the original or subsequent dolomitization of the rock. This question is outside the immediate interests of the paper.

2. The Coral remains occur sometimes in isolated blocks, sometimes in large clumps of rock perforated by *Thecosmilia* species of Coral, and often full of fragments of Echinoderms. These blocks or clumps occur in the midst of fine volcanic mud, or the calcareous and dolomitic matter of the contemporaneous marine sediment, and form more or less continuous beds with lenticular reef-like expansions. The name they go by is "*Cipit Limestones*," and they vary from 10 feet to 150 feet in thickness.

3. "Cipit Limestones" are of episodal occurrence throughout the mid-Triassic era, appearing at entirely irregular horizons of all Triassic strata between the Muschelkalk and Dachstein dolomite. At the same time, in the area under discussion, there is one horizon pre-eminent for the interbedding of Cipit Limestones, that is, the Cassian.

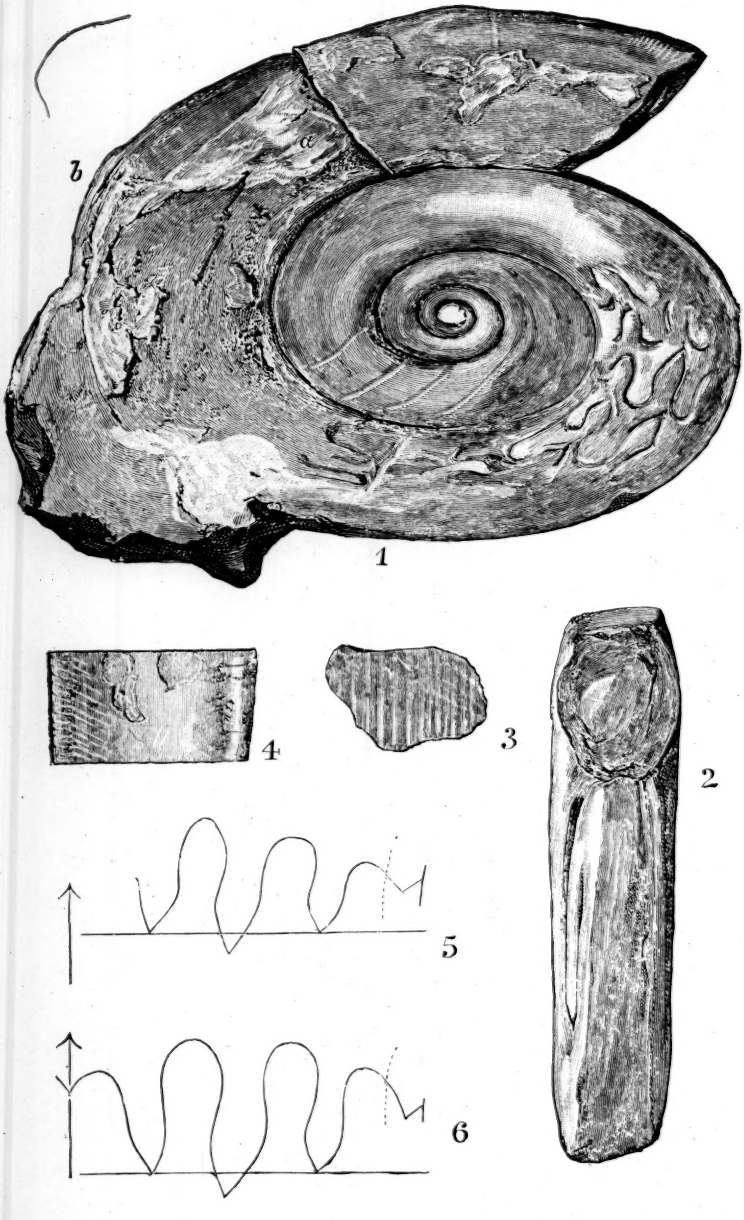
4. In its lithological character and faunal distribution, the Wengen and Cassian period shows marked heteropism. While in deeper seas algæ grew and Mollusca prevailed, there was, not far from the island coasts of the mid-Alpine core of rocks, a zone of submarine volcanic eruption. Lavas and ashes were swept intermittently over the sea-floor. Along the hem of this volcanic girdle communities of Corals and Echinoderms settled and formed a series of small barrier reefs (Cipit Limestones), frequently interrupted in their growth by fresh lavas. On the outer, seaward side, marine deposits continued to increase in thickness over a sinking basin; on its inner side, at first only a few mud-loving species of *Halobia*, *Posidonomya*, etc., could exist, but later the Cassian fauna enjoyed a varied and rapid development, and lived on good terms with the Reef-fauna of the Cipit Limestones.

5. The fossiliferous marls and Cipit Limestones of Cassian age in Enneberg are succeeded by a calcareous and dolomitic rock, which is of the same age as the upper horizons of the calcareous and dolomitic marine deposits of mid-Triassic age in the south and south-west. Taking one or two parallel lines of section north and south through the inner Cassian belt of deposit, we find that Schlern dolomite succeeds, in the west or Gröden area, an extremely irregular submarine relief of volcanic, sedimentary, and reef-rocks of Wengen and Cassian age; in the Enneberg area it succeeds reef-rocks and the famous fossiliferous Cassian marls of Stuores meadow; in the Ampezzo and easterly regions it succeeds reef-rocks and fossiliferous marls, belonging to a somewhat later palæontological zone, Upper Cassian.

6. Contemporaneous faulting and volcanic action were the cause of mid-Triassic heteropism in South Tyrol.

Hence, so far as positive evidence goes, the Coral rocks of South Tyrol in the Wengen and Cassian period are not the majestic mountain massifs of dolomite, but much less obtrusive, lenticular masses of limestone. And one general law may be said to govern the Wengen and Cassian period in Gröden, Enneberg, and Ampezzo, a wandering north-eastwards of the Wengen and Cassian fauna (including the special reef-fauna of the Cipit Limestones) consequent on the cessation of volcanic activity along the immediate southern boundaries of the Cassian-Enneberg sea, and the increasing subsidence of these areas. During the subsiding movement, sea algæ and large Mollusca pressed northward. The shallow-water Cassian-Enneberg fauna, no longer enjoying the same favourable conditions as before, retreated into more and more limited localities and gradually gave place to its lineal descendants, the shallow-water fauna of Raibl times. This transitional period paved the way for the complete recovery of normal conditions in Fassa, Gröden, and Enneberg. As Mojsisovics has said, South Tyrol in Raibl times "participated once more in the general movements of Alpine areas."

(*To be concluded in our next Number.*)



Prolecanites compressus, J. Sby. sp.

FIGS. 1–5. Carboniferous Limestone, near Cork, Ireland.
FIG. 6. Carboniferous Limestone, Scarlet, Isle of Man.

II.—On the Identity of *Ellipsolites compressus*, J. Sowerby, with *Ammonites Hensiowi*, J. Sowerby.

By Arthur H. Foord, F.G.S., of the Royal Dublin Society, Dublin; and
G. C. Crick, Assoc.R.S.M., F.G.S.,
Assistant in the Geological Department, British Museum (Nat. Hist.).

(PLATE I.)

(i.) *Introduction.*

Ellipsolites compressus, J. Sowerby (Min. Con. vol. i. p. 84, pl. xxxviii. 1813), has been hitherto usually regarded as a Nautiloid,[1] and referred either to *Nautilus* or to *Discites*.

During an examination of the collection of Mr. Joseph Wright, of Belfast, by one of the present writers, a fossil from the same horizon, and almost the same locality as the type-specimens of *Ellipsolites compressus* of J. Sowerby, was observed, so much resembling Sowerby's species (but exhibiting also the character of the suture-line) that a comparison with, and a re-examination of, Sowerby's types was suggested.

Mr. Wright has very kindly lent us this fossil, so that we have been enabled to compare it closely with Sowerby's figured specimens, both of which are in the British Museum (Natural History), and we would take this opportunity of returning to Mr. Wright our sincere thanks for the loan of his specimen, which has served to throw much light upon the character of Sowerby's species.

When describing his species, Sowerby was evidently unacquainted with the suture-line, for, in speaking of the larger of the two specimens which he figured, he says "the crystallization seems to have helped to obliterate the chambers, if there were any," and, in referring to the smaller of the two specimens, he says nothing whatever about the septa. After very careful examination we have not been able to detect any trace of septa in the larger specimen, but in the smaller example the suture-line is somewhat indistinctly visible at about the commencement of the last whorl.

(ii.) *Description and determination of a specimen in the collection of Mr. Joseph Wright, Belfast.*

Mr. Wright's specimen is considerably larger than the larger of the two specimens figured by Sowerby, which, by the way, is a little

[1] *Nautilus compressus*, J. Fleming, Brit. Anim., 1828, p. 231; *id.* De la Beche, Geological Manual, 1831, p. 448; *id.* Goldfuss, in v. Dechen's Handb. d. Geognosie, 1832, p. 536; *id.* T. Weaver, Trans. Geol. Soc. [2], vol. v. 1837, p. 22; *id.* L. Agassiz, in E. Desor's Translation of Sowerby's Min. Con. 1842, p. 27; *id.* R. Griffith, Notice respecting the Fossils of the Mountain Limestone of Ireland, as compared with those of Great Britain, and also with the Devonian System, 1842, p. 21; *id.* A. D'Orbigny, Prod. de Paléont., vol. i. 1850, p. 110; *id.* C. G. Giebel, Fauna der Worwelt, vol. iii. 1852, p. 178; *Nautilus* (*Discites*) *compressus*, J. Morris, Cat. Brit. Foss., 2nd ed. 1854, p. 308: *Nautilus compressus*, L.-G. de Koninck, Faune du Calcaire Carbonifère de la Belgique (Annales du Mus. Roy. d'Hist. nat. de Belgique, vol. ii.), pt. i. 1878, p. 122; *Discites compressus*, R. Etheridge, Fossils of the British Islands, vol. i. Palæozoic, 1888, p. 310; *id.* A. H. Foord, Cat. Foss. Ceph. Brit. Mus. (Nat. Hist.), vol. ii. 1891, pp. 86 and 91; *id.* A. H. Foord and G. C. Crick, Geol. Mag. Dec. III. Vol. X. 1893, p. 253.

larger than the figure. It is somewhat elliptical, its diameters being 172 mm. and 142 mm. respectively. It was obtained from the Carboniferous Limestone of Little Island, Queenstown Harbour, opposite Blackrock, the locality which yielded Sowerby's types.

The sides of the whorls, especially in the septate portion of the shell, are flattened, feebly convex, their greatest convexity being at about the middle of the lateral area; the sides of the body-chamber are slightly inflated. In the outer whorl the portion of the lateral area adjoining the periphery becomes somewhat concave. The periphery is flattened, and bounded on either side by a subangular edge; at the commencement of the outer whorl the periphery is rather convex in the centre and somewhat concave between the centre and the subangular border. As the shell increases in size the peripheral area becomes more flattened, and its edges more prominent (see Fig. 4), so that the concavity of the portion of the lateral area adjoining the periphery becomes more pronounced. Rather more than three and a half whorls can be counted, but the central portion of the fossil—*i.e.* up to the point where the diameters of the shell were 11 mm. and 9 mm. respectively—is wanting. The inner area of the whorl is well defined, and slopes towards the umbilicus; this slope has probably been increased by the distortion which the specimen has suffered owing to the cleavage of the rocks in which it was imbedded. The slope is apparent, though less distinctly marked on the body-chamber, and where the shell is absent this inner area is scarcely defined on the cast.

The latter half of the outer whorl is occupied by the body-chamber; it bears only fragments of the shell. One side of the septate portion of the specimen is covered by the test. This exhibits an almost perfectly smooth surface; there are no traces of longitudinal lines on any of the inner whorls. On the last part of the septate portion, that is, on the first half of the outer whorl, there are, however, very faint indications of fine transverse curved lines sweeping forward near the periphery. A constriction near the commencement of the last whorl follows the course of these transverse lines, and doubtless indicates the form of a previous aperture. The form of the constriction cannot be clearly made out on the periphery. The other side of the last half whorl of the septate portion is denuded of the test, so that the septa are shown very distinctly.

Some fragments of the test remaining on the body-chamber are very well preserved. They show that on the lateral area of the body-chamber the test was nearly smooth, marked only with fine, subregular, faintly-incised lines about one millimetre apart (see Fig. 3), which extend in an almost radial direction over the middle portion of the side of the whorl and sweep forward as they approach the periphery, meeting the margin of the latter at an angle of about 50°, and forming on the subangular margin prominent imbricating lines. These fine lines cross the inner area of the portion of the whorl forming the body-chamber in a rather shallow curve, concave forwards.

Owing to a fracture, a portion of the cast of the body-chamber can be detached from the rest of the specimen. Its anti-peripheral side displays a concave impressed zone, bounded on either side by a rounded ridge, which bears a very shallow longitudinal groove. Where denuded of the test this anti-peripheral area shows "epidermids," which on the concave portion have the form of short, rather coarse, interrupted, transverse, impressed, wavy lines, but at the ridges on either side they become much finer and more pit-like. The condition of the fossil is such that these epidermids cannot be definitely made out on the sides of the body-chamber; but on the periphery, near its subangular margin, their punctate character can be distinctly seen.

The character of the septa (see Fig. 5) suggested at once a comparison with such forms as "*Ammonites Henslowi*," J. Sowerby,[1] and "*Goniatites vinctum*," J. de C. Sowerby.[2]

The type of the latter species, from the Upper Devonian of South Petherwin, Cornwall, is in the Woodwardian Museum, Cambridge, but according to Sowerby's figure its suture-line differs from that of Mr. Wright's specimen in having fewer lobes on the lateral area.

One of the specimens of "*Ammonites Henslowi*" figured by Sowerby is also in the Woodwardian Museum, Cambridge, and there are some examples of the species in the British Museum (Natural History). A specimen in the Sowerby collection in the latter Museum, although a cast and partly imbedded in matrix, exhibits the convex periphery with a small portion of shell adhering to the periphero-lateral margin, indicating the former presence of a prominent ridge at this part.

The writers, however, are greatly indebted to Miss C. Birley, of Manchester, for the loan of an interesting series of examples, whereby most of the characters of this species are clearly shown. All these specimens are casts and exhibit no trace whatever of the shell-structure.

A comparison with these specimens showed that the septa of Mr. Wright's example agree perfectly with those of Sowerby's species (see Fig. 6), and the general characters of the shell also agree. In Sowerby's species the sides of the whorls are flattened, but they have their greatest convexity at about the middle of the lateral area as in Mr. Wright's specimen. The subangular edges of the peripheral area are shown only at one part of Sowerby's specimen, but an example of his species in the Sowerby Collection in the British Museum (Nat. Hist.) exhibits this character and they are particularly well shown in two of Miss Birley's specimens. This character appears, however, to be seen usually only in specimens which have a portion of the body-chamber preserved, for, whilst an example of more than 180 mm. in diameter, but consisting only of

[1] Min. Con., vol. iii. p. 111, pl. 262, April, 1820. Sowerby figures two specimens; that represented in the upper figure is in the Woodwardian Museum, Cambridge; the whereabouts of the other specimen is unknown to the present writers.

[2] Trans. Geol. Soc. [2], vol. v. pl. 54, fig. 18.

the septate portion of the shell, does not display the subangular character of the peripheral edges, the two specimens which exhibit this character best are only 138 mm. and 145 mm. in diameter respectively. The same two examples show also the concavity of the portion of the lateral area of the whorl adjoining the peripheral region as well as the inflation of the sides of the body-chamber observable in Mr. Wright's specimen.

There cannot, therefore, be any doubt, we think, as to the species to which Mr. Wright's specimen must be referred. It clearly belongs to the species which Sowerby described as *Ammonites Henslowi*.

(iii.) *Comparison of Mr. Wright's specimen with Sowerby's types of* Ellipsolites compressus.

J. Sowerby figured two specimens to illustrate his species *Ellipsolites compressus*; as we have already stated, both figured specimens are in the Sowerby Collection in the British Museum (Natural History). In the larger of these specimens we have failed to find any trace of the septa, but the general characters of the shell—its evolute form; the wide umbilicus; the shape of the whorls, the form of the periphery, the flattening of the sides, their feeble convexity and the position of their greatest convexity, the nature of the inner margin—agree so closely with those of Mr. Wright's specimen that there cannot, we think, be any doubt of their identity.

In the small specimen figured by Sowerby the suture-line is somewhat indistinctly visible, as we have already remarked, at about the commencement of the outer whorl. When this is compared with the suture-line on the inner whorl of a large specimen of "*Ammonites Henslowi*" at a point where the diameter of the shell is about the same as that at the place where the suture-line is seen on the specimen, the two are found to closely resemble each other. The nature of the surface of Sowerby's specimen, however, does not enable us to follow its suture-line as well as we could wish, but the small specimen agrees so well in its general form and rate of increase with the larger specimen figured by Sowerby, and moreover is from the same locality, that it is most probable they are examples of the same species.

The smaller of the two specimens has some resemblance to M'Coy's figure of *Goniatites discus*.[1] In the "[Sir Richard] Griffith Collection" of the Museum of Science and Art, Dublin, there is an example of this species which agrees so well with M'Coy's figure (except that the figure is reversed) as to size, form, and even the fracture of the end of the last whorl, that it may be M'Coy's type, although there is no information with the specimen to that effect. It is a natural cast, partly buried in matrix. Although a portion of the surface of the fossil has been ground away to show the suture-line, this was still somewhat indistinct, but by slightly polishing the

[1] F. M'Coy, Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland, 1844, p. 13, pl. ii. fig. 6.

specimen at the point where the suture-line was seen to be present, after very careful examination we have been able to satisfy ourselves that the first lateral lobe is not divided, as M'Coy's figure indicates, but that it terminates in a single point; and further, that the peripheral (or external) lobe is not V-shaped, as M'Coy represents, but that it is shaped somewhat-like the lateral lobes, being slightly contracted above, expanded below and terminating in a rather acute point. We notice that at one part of the specimen the peripheral lobe appears to be V-shaped, but the posterior portion of the lobe is not sharp, and the whorl has here been ground away to a depth of more than one-half of a millimetre, a considerable amount, since the height of the whorl when complete was only nine millimetres.

In all the specimens of "*Ammonites Henslowi*" that we have been able to examine, the peripheral lobe is V-shaped, but as we have not been able to observe the periphery of a young shell, *i.e.* of a shell of about the same diameter as M'Coy's *Goniatites discus*, we cannot say if at this age the peripheral lobe is V-shaped or if it has the form of the lateral lobes, as in M'Coy's species.

Although the latter is evidently closely allied to Sowerby's species, M'Coy's *G. discus* appears to have been not only a less rapidly increasing, but also a smaller shell, for in the specimen above referred to, which is about 42 mm. in diameter, about one-third of the last whorl is occupied by the body-chamber.

We do not think it possible that Sowerby's *Ellipsolites compressus* can be a badly-preserved specimen of what he later on described as *Nautilus complanatus*,[1] from the Carboniferous Limestone of Scarlet in the Isle of Man, for, in describing the latter shell, Sowerby states that the periphery is rounded, and it must be observed that his type has, according to his figure, a large portion of the body-chamber preserved. Further, in the latter species the greatest thickness of the whorls is at the margin of the umbilicus, whereas in *Ellipsolites compressus* it is at about the middle of the lateral area.

We arrive, therefore, at the conclusion that Mr. Wright's specimen is specifically identical with the two examples figured by Sowerby as *Ellipsolites compressus*, and that all three specimens are examples of the species which Sowerby described later as *Ammonites Henslowi*.

(iv.) *Observations on the Name of the species.*

Having established the identity of Sowerby's *Ellipsolites compressus* with his *Ammonites Henslowi*, it remains for us to offer some remarks upon the name of this shell.

(*a*). First as to the genus:—

In the first place we will consider the name *Ellipsolites compressus*.

The genus *Ellipsolites* was founded by Denys de Montfort[2] in 1808, his type being *E. funatus*, a cretaceous Ammonite from Mount St. Catherine, near Rouen. To de Montfort's genus Sowerby referred three species from the Carboniferous Limestone, Blackrock, near

[1] Min. Con., vol. iii. 1820, p. 109, pl. 261. The type-specimen is in the Woodwardian Museum, Cambridge.

[2] Conchyliologie systématique, 1808, vol. i. p. 86.

Cork, viz. *E. funatus*,[1] *E. ovatus*,[2] and *E. compressus*,[3] regarding the first, although from the Carboniferous Limestone, as specifically identical with de Montfort's type. The suture-line of *E. compressus*, not to speak of the other two species, excludes it absolutely from de Montfort's genus.

De Haan,[4] in 1825, placed Sowerby's *E. compressus* in the comprehensive genus *Planulites*, Montf.[5] (or, as he preferred to spell it, *Planites*), but even if this name be retained in a restricted sense, de Montfort's type differs so considerably from Sowerby's species that the two cannot be placed in the same genus.

In 1831 Parkinson,[6] observing that "two very different shells have [had] been placed under the genus *Ellipsolithes* (Sowerby), both oval and discoidal shells; but one possessing the involved whirls and the plain septa of *Nautilus*, and the other the whirls, apparent on both sides, and the winding septa of *Ammonites*," divided the genus, and gave the name *Nautellipsites* to the former, referring to it (pl. vi. fig. 3) the *E. ovatus*, J. Sowerby, and the name *Ammonellipsites* to the latter, referring to it the *E. funatus* and *E. compressus* of Sowerby, the figure of his type (pl. vi. fig. 4) of this division probably representing Sowerby's *E. funatus*. Even if Parkinson's name *Ammonellipsites* be retained, it must be used for the group of shells allied to *E funatus* of Sowerby, a shell which differs considerably from Sowerby's *E. compressus*.

Münster[7] prefaces the description of his *Goniatites spurius* with the remark, "near to *Ellipsolites compressus?* Sowerby Tab. 38," and Bronn in his "Index Palaeontologicus" (p. 545) regards Sowerby's *E. compressus* as a synonym of Münster's *Goniatites spurius*; but Münster's description of the suture-line of the latter suffices to show that the two species are not identical.

Sowerby seems to have considered *E. compressus* to be an Ammonoid, for, writing in 1821[8]—eight years after the publication of the description of his species—he says:—"The genus *Ellipsolithes* must certainly be abolished, and its species ranged under *Ammonites*, the oval form being quite accidental." Many authors,[9] however, not having seen the septa, regarded Sowerby's species as a *Nautiloid* and referred it, either to the genus *Nautilus*, or to the genus *Discites*, but the character of the septa, as now recognized, at once excludes it from these divisions.

According to our present knowledge of *E. compressus*, we cannot rightly adopt any of the interpretations, which, so far as they are known to the writers, have hitherto been given of this species.

Let us consider in the next place the name *Ammonites Henslowi*.

[1] Min. Con., vol. i. p. 81, pl. xxxii. 1813.
[2] Ibid. p. 83, pl. xxxvii. 1813.
[3] Ibid. p. 84, pl. xxxviii. 1813.
[4] Monog. Ammon. et Goniat., 1825, p. 93.
[5] Conchyliologie systématique, 1808, vol. i. p. 78.
[6] Introduction to the Study of Fossil Organic Remains, 1822, p. 164.
[7] Planul. und Goniat., 1832, p. 30; Beiträge, Heft i. 1843, p. 23.
[8] Min. Con., vol. iii. p. 167, footnote.
[9] See footnote, antea, p. 11.

This species has been referred also to *Ceratites*,[1] *Aganides*,[2] and *Goniatites*,[3] usually, however, to the latter.

Owing to the badness of the figure which accompanies his description, de Montfort's genus *Aganides*[4] has been variously interpreted[5]; but, whatever de Montfort's figure is intended to represent,[6] Sowerby's *A. Henslowi* is a very different shell, as regards both form and suture-line, and certainly cannot be assigned to the genus *Aganides*.

Although placed in the genus *Ceratites* by de Haan,[7] the author of the genus, the suture-line of *Ceratites*, as that genus is now restricted, differs widely from that of *A. Henslowi*.

Ammonites Henslowi is referable to the genus *Goniatites*, of authors, but this, like *Ammonites*, is now considerably subdivided. The division into which Sowerby's species falls has been named by Mojsisovics *Prolecanites*,[8] and it is to this genus that Sowerby's species is now usually referred.[9]

(*b*) Next as to the species:—

Of the two names given by Sowerby, *Ellipsolites compressus* was described in 1813, and *Ammonites Henslowi* in 1820; therefore, according to the law of priority, the specific name *compressus* must supersede that of *Henslowi*.

Hence the name of the shell under consideration becomes *Prolecanites compressus*; and *Ellipsolites compressus*, J. Sowerby, and *Ammonites Henslowi*, J. Sowerby, are synonyms of it.

EXPLANATION OF THE PLATE I.

Prolecanites compressus, J. Sby., sp.

FIG. 1. Lateral aspect of a specimen in the collection of Mr. Joseph Wright, Belfast. About ½ nat. size.
,, 2. Front aspect of the same. About ½ nat. size.
,, 3. Portion of the test (marked *a* in Fig. 1). Nat. size.
,, 4. A portion of the periphery, as seen at the point marked *b* in Fig. 1, showing the subangular borders and the sculpture of the shell. Nat. size.
,, 5. The suture-line marked *c* in Fig. 1. Nat. size.
,, 6. Suture-line of a specimen (No. C. 3496) from the Carboniferous Limestone, Scarlet, Isle of Man, presented to Brit. Mus. (Nat. Hist.) by Miss C. Birley.

FOOTNOTE.—While this paper was in the press, Mr. Wright has, through one of the writers, kindly presented the specimen (here described) to the British Museum.

[1] *Ceratites Henslowi*, de Haan, Monog. Ammon. et Goniat., 1825, p. 157.

[2] *Aganides Henslowi*, A. D'Orbigny, Prod. de Paléont., vol. i. p. 115; *id.* F. M'Coy, Brit. Pal. Foss., 1855, p. 564.

[3] *Goniatites Henslowi*, J. Phillips, Geol. Yorkshire, pt. 2, 1836, p. 236, pl. xx. fig. 39; *id.* d'Archiac and de Verneuil, Trans. Geol. Soc. [2], vol. vi. 1842, p. 329; *id.* J. Morris, Cat. Brit. Foss., 2nd ed. 1854, p. 303; *id.* C. Barrois, El marmol amigdaloide de los Pirineos (Boletin de la Comision del Mapa geologico de Espana, vol. viii.), 1881, p. 9, pl. C. figs. 3*a*, 3*b*, 3*c*; *id.* R. Etheridge, Fossils of the British Islands, vol. i. Palæozoic, 1888, p. 311; etc.

[4] Conchyliologie systématique, 1808, vol. i. p. 30.

[5] See notes on de Montfort's genus by F. B. Meek, Geol. Surv. Territ., vol. ix. 1876, p. 494.

[6] P. Fischer (Manuel de Conchyliologie, 1880-87, p. 380) states that the species figured by de Montfort is *Goniatites rotatorius*, de Koninck.

[7] Monog. Ammon. et Goniat., 1825, p. 157.

[8] E. v. Mojsisovics, Abhandl. d. k.k. geol. Reichsanst., vol. x. 1882, p. 199.

[9] *Prolecanites Henslowi*, E. v. Mojsisovics, *loc. cit.*; *id.* K. A. von Zittel, Handb. d. Palæont., vol. i. 1884, p. 421; *id.* E. Holzapfel, Palæont. Abhandl., Dames and Kayser, n.s. vol. i. 1889, p. 42, pl. iii. fig. 14, pl. iv. figs. 2, 4, 7; *Goniatites* (*Prolecanites*) *Henslowi*, J. Seunes, Comptes Rendus, vol. cxv. 1892, p. 681.

III.—Note on a New Species of *Æpyornis* (*Æ. titan*).

By C. W. Andrews, B.Sc., F.Z.S.

In a collection of vertebrate remains from the south-west coast of Madagascar, recently received in the British Museum, there occur numerous bones belonging to, at least, three species of *Æpyornis*. Among them are two tibio-tarsi, right and left, of gigantic size, much larger than any hitherto described. Both these bones are, unfortunately, considerably damaged at the upper end, the right one alone showing any portion of the proximal articular surface. They both, without doubt, belong to the same species, though probably not to the same individual. The left, which on the whole, is the better preserved, may be taken as the type of the species which it is proposed to call *Æpyornis titan*.

A very massive femur from the same collection probably belongs to the same species. There are also several more or less imperfect femora, which are slightly smaller and of rather different proportions. All the bones have a very fresh appearance.

The *tibio-tarsus* has the following dimensions in centimetres, those of *Æ. maximus*, Is. Geof. and *Æ. Hildebrandti*, Burck. being quoted for comparison from the memoirs of Milne Edwards, Grandidier, and of Burckhardt.

Measurements of the tibio-tarsi of *Æpyornis*.	*Æ. titan*.	*Æ. maximus*.	*Æ. Hildebrandti*.
Length	80·0[1] cm.	64·0 cm.	48·5 cm.
Width of distal end	17·0 ,,	13·5 ,,	8·2 ,,
Width of shaft at the narrowest point...	7·5 ,,		
Circumference at the narrowest point ...	20·7 ,,	15·5 ,,	11·0 ,,
Shortest antero-posterior diameter	4·5 ,,		

The shaft of the bone is slightly curved with the concavity inwards. The anterior surface of the lower two-thirds is flat and is bounded on either side by ridges, the inner being the stronger, which separate it from the lateral surfaces. The upper portion is traversed by a *linea aspera*, which is continuous with the lower end of the pro-cnemial crest and runs downwards and inwards, reaching the inner border of the bone about 32 cm. from its distal end; here it is continuous with the inner ridge above mentioned. Immediately above the articular surface is a longitudinal ridge with a rugose tubercle at its lower end. Between this and the inner border is the groove for the extensor tendons of the digits, deepest distally and soon dying away as it is traced upwards. The extensor bridge is unossified. The lateral and posterior surfaces form a continuous curve, nearly semicircular in section in the middle of the shaft, but becoming flattened posteriorly as the bone widens towards the distal articulation. The shaft is also flattened externally near its lower extremity. The surface of attachment for the fibula closely resembles that in *Æ. maximus*. The condyles project considerably forwards, the inner being the larger and more prominent. Their

[1] This measurement is taken from the right-hand specimen and is only approximate.

lateral surfaces have large pits for the insertion of ligaments, that in the ectocondyle being about 2·5 cm. deep. Behind these pits are large rough tuberosities. The intercondylar surface is only slightly depressed, and, though faintly convex from side to side, does not show the strong ridge figured by Burckhardt in *Æ. Hildebrandti*. The upper portion of the bone is too imperfect for description.

The *left femur*, which is provisionally referred to the present species, is nearly complete, only the upper part of the massive trochanter and the anterior part of the condyles being lost. Its dimensions are as follows:—

Measurements of the femora of *Æpyornis*	*Æ. titan.*	*Æ. maximus.*	*Æ. Hildebrandti.*
Approximate length	41·5 cm.	32·0 cm. (? true length)	
Circumference of shaft at the narrowest part	27·3 ,,	27·0 cm.	15·8 cm.
Width of shaft at the same point.....	9·2 ,,	9·1[1] ,,	5·0 ,,
Width of distal end (approximate)	21·0 ,,	19·0 ,,	10·0 ,,

The neck is short and thick, measuring 23 cm. in circumference; its anterior surface is very rugose. The upper articular surface of the trochanter is flat and continuous with that of the head, from which it slopes steeply upwards and outwards, widening rapidly. The trochanter seems to have risen considerably above the head, but does not form a crest strongly projecting forwards, as in *Dinornis*. On the posterior surface, near its junction with the neck, is a pneumatic foramen, the exact size and shape of which cannot be determined owing to the fracture of its edges. The passage into which this foramen opens is very large, measuring about 3 cm. from side to side and 1·5 cm. from before backwards; this runs down to about the middle of the shaft, where it terminates in the complex bony network with which the bone is almost entirely filled, as can be seen in one of the smaller femora which is broken across. The shaft is narrowest about 12 cm. below the upper surface of the neck; at this point it is oval in section, the short diameter being antero-posterior. The flattening becomes much more pronounced as the bone widens out towards the condyles, so that just above these the anterior face is only slightly convex from side to side. The lower portion of the posterior face is occupied by the popliteal fossa; this is triangular in outline, the lower side being formed by a very strong rounded intercondylar ridge, the inner by a rough border terminating above in a blunt tubercle, while externally the side of the fossa slopes gently up, passing imperceptibly into the posterior surface of the shaft. Several pneumatic foramina open into this fossa, the largest measuring 7 by 5 mm. The condyles, which are very massive, are unfortunately somewhat incomplete. The outer projects about 5 cm. beyond the inner and has a rough concave external surface. The articulation for the fibula is narrower relatively than

[1] This measurement is taken from a cast in the British Museum. It seems probable that this femur does not belong to *Æ. maximus*, but to the present species.

in *Dinornis*. The intercondylar fossa is scarcely perceptible and the rotular surface is little depressed; owing to fracture it cannot be seen how far the condyles projected forwards beyond its level.

In the same collection is a very incomplete proximal end of a metatarsus, perhaps belonging to this species.

IV.—Augen-Structure in Relation to the Origin of the Eruptive Rocks and Gneiss.[1]

By J. G. Goodchild, F.G.S., H.M. Geological Survey.

AMONGST the rocks whose original structures have been more or less deformed by metamorphic agencies the geologist very commonly meets with curious eye-like inclusions of mineral matter, which are generally known by the name of augen. Close investigation of a large series of rocks exhibiting these eyes brings to light the fact that under this name are classed two essentially different kinds of structure. In the one, the kernels or eyes are manifestly the unsheared portions of the rock, whose sheared portions constitute the schist that envelops the eyes. In the other kind of augen structure the eyes consist of crystalline minerals, whose development as such is shewn to be posterior to the shearing to which the matrix has been reduced, by the fact that the eyes of crystalline matter have not participated in the shearing, but are bright and generally unfractured throughout. It is here suggested that the term "flaser structure" should be confined to the results of uncompleted shearing, where the eyes were formed contemporaneously with the movements; while to the structure seen in the rock containing the crystalline augen developed after the shearing movements had ceased, it is suggested that the term "augen structure" should be restricted.

Augen structure occurs under two sets of conditions. In the one, the constituents out of which the augen have been formed were already in existence within segregating distance, when the rock was first subjected to metamorphic action, and their development is merely a case of regeneration under plutonic conditions, whose general nature will be discussed presently. In the other set of augen, the rock in which the structure occurs did not originally contain the whole of the constituents that were essential for the formation of the eyes. Part of these constituents must, therefore, have been introduced from an outside source, some time late in the history of the rock, but possibly only a short time prior to the date when the causes concerned in the development of the augen came into action. In the simpler case, where the constituents existed within the rock from the first (which may be typified by augen amphibolite), a crystalline development has been set up in the rock at various disconnected points, while the surrounding material, although very generally granulitised, still remains in a schistose state.

Assuming that heat, co-operating in any one of various ways with chemical action, is an essential factor in the generation of the

[1] This is substantially part of a Lecture on the "Causes of Volcanic Action," delivered under the auspices of the Royal Scottish Geographical Society at Edinburgh, December, 1892.

crystalline matters under notice, our chief difficulty in attempting to explain these facts lies in accounting for the generation of the conditions necessary for fusion, at isolated centres within a rock, while the matrix, consisting of the very same mineral matter, should remain unfused. The molecules, in some way or another, have been locally placed under such conditions as to permit of their taking up different positions from what they had when first acted upon; and yet the conditions referred to have been in action only at certain points, or along certain zones, contiguous to others that have not been so affected. It seems obvious from this consideration that the result cannot be due to the simple action of heat from an external source, such as would arise either from contact with molten masses, or from any heat proceeding from the earth's interior.

This and other reasons of the same kind have led the author to advocate the view, previously advanced by others, that the chief cause of the high temperature prevailing within the earth's crust lies in the conversion of the motion arising from earth-creep into heat. It is assumed that the heat generated in this way augments with depth below the surface, until a temperature is ultimately reached which is higher than that necessary to fuse the most refractory of the rock constituents. Amongst many other causes that contribute to bring about such differential movements of the earth's crust, and therefore to generate subterranean heat, the author is disposed to rank lunar attraction as one of the chief. Where earth-creep takes place under comparatively small superincumbent pressure in the presence of water, the rocks are simply deformed, crushed, or ground, or otherwise affected, by causes which are chiefly of a mechanical nature. At greater depths differential movements give rise to what Teall has aptly termed plastic deformation—the rock material being actually made to flow in the direction of least resistance, so that what may be termed dynamo-fluxion structure is impressed upon the rock.

Good examples of this plasticity of solids when compelled to change their form under great pressure are afforded in the mechanical arts in the process of moulding from the solid metal the nickel bullet cases in use in the British army. A "burr" of sheet nickel is forced, cold, through a succession of annular dies, the first one giving rise to a shallow cup with thick sides, while the passage through each successive die increases the depth of the cup and lessens the thickness of its sides, until in the end a tube of solid metal of the required thinness and length is fashioned. The rate of movement and of pressure have to be carefully adjusted to each other so as to obtain the requisite degree of plasticity without permitting the motion to be converted into a degree of heat sufficient to produce actual fusion from the pressure employed.

In the case of subterranean movements affecting rocks at great depths, the temperature, generated by the conversion of the motion into heat, must generally be more than sufficient to bring about the fusion of even the most refractory of the rock-forming minerals. When subjected to the great undulatory movements which have

certainly affected the earth's crust, even at great depths from the surface, the deeper-seated rocks must constantly tend to pass into the molten condition, but are prevented from melting owing to their fusing point being raised in consequence of the superincumbent pressure. But if this superincumbent pressure is relieved while the rocks are in the potentially molten condition referred to, they pass at once into the molten state. The same result follows, of course, if the temperature rises while the pressure remains constant. A relief of pressure is thus equivalent in this case to a rise of temperature, and is, for several reasons, the more likely cause of fusion.

Once these rocks are reduced to the molten condition they tend to eat their way upward in any direction of least resistance—the place of the material flowing upwards being at first taken chiefly by the colder masses of rock, which sink within the magma as fast as they are quarried from the sides of the vent. On arriving within a few miles of the surface the heated rock occludes H_2O and is thereby rendered more fluid, and at the same time receives an additional impulse through the elastic force exerted by the included gases. These finally impel the molten rock to the surface, and when the communication between the plutonic zones of fusion and the surface of the earth is finally established, a volcano is the result.

The products of dynamo-metamorphism may not reach the surface, but may be arrested at any horizon between their starting-point and the surface. Volcanic products therefore graduate downward through the trappean into the plutonic rocks, which, in their turn, terminate, at great depths, against the zones of dynamo-fusion.

When once volcanic action has commenced, the place of the ejected material is partly taken by the downward subsidence of the volcanic centres, partly filled in by a lateral flow of rock-material towards the deeper parts of the foci. As this movement itself takes place under enormous pressure, it not only tends to produce schistosity in the rocks within the zones affected, but it must at the same time give rise to a further evolution of heat.

Such results as those just noticed follow when the relief of pressure upon a potentially molten mass acts *per saltum*. This mode of relief must often come into action, more especially in connection with the subterannean explosions, which are due to the sudden access of water to greatly heated masses, or to the sudden relief afforded when the tension of the vapour thus imprisoned overcomes the resistance. But in quite as many cases, more especially within the deeper zones of the earth's crust, the relief of pressure is directly connected with the translation of the great terrestrial undulations from one part to another. Such undulations, as a rule, may be supposed to travel at very slow rates, so that it may require an interval of many thousands of years for an upward phase of an undulation to pass into a phase of movement in the opposite direction. Assuming that differential compression of the rocks acted upon is one of the results of all such undulatory movements, it would follow that, by slow degrees, the locus of greatest pressure travels with the undulation, and gives place, also by very slow degrees, to one in

which the pressure would be at a minimum for that depth from the surface. Rocks affected in that manner must, almost of necessity, undergo more or less shearing, and as it is well known that heat travels through sheared rocks more readily along their planes of schistosity than in directions transverse to them, higher temperature prevails there from that cause alone. But schistose rocks, subjected to lateral pressure, must give way more readily along their own planes of maximum structural weakness than along any others. Consequently, even a slight separation of the rock along these planes gives rise to a relief of pressure, which, by degrees, tends to bring about a gradual fusion at the points where the relief of pressure has been greatest. The fusing points attained in such a case would bear a definite relation to the ratio between the initial and final pressure while the temperature remained constant.

If, now, the earth movements cease, or the temperature falls, the fused portions of the rock gradually crystallise out, and eventually appear as augen set in a sheared matrix composed of the very same minerals which have not had any opportunity of returning to the crystalline condition. This local fusion, through gradual relief of pressure acting upon rocks that are in a potentially molten condition, forms the starting point of some phenomena of considerable interest in the history of rock structures. The two examples so far considered have been those of rocks consisting mainly of amphibolite. In the one case, these have been sheared into phacoids by mechanical action without any subsequent chemical rearrangement of the minerals affected. In the other case, molecular rearrangement has been superinduced upon the results of mechanical deformation, and amphibolite augen have been formed. But in many cases the rocks acted upon have been of much less simple composition, and have included the constituents of more than one or two minerals. In rocks of such nature the fusing point of any one mineral of the compound may differ considerably from that of the others. Assuming that three such minerals are present, which for the present purpose may be denoted respectively by A, B, and C, the fusing point of one of them—A, under given conditions, may lie below that of B; while B in its turn fuses, under the same conditions, at a lower temperature than C. If now the entire compound be subjected to a temperature which is sufficent under a low pressure to fuse C, but which temperature is, at the same time, counteracted by heavy pressure, so that not only C, but B and A, remain unfused, the minerals will all remain practically unaffected. But if the temperature rises sufficiently to fuse A under the same pressure, or if, what amounts to the same thing, the pressure is slowly and gently eased off, then A may pass into the molten state, leaving B and C as they were. Similarly with a further relief of pressure, the temperature remaining as before, B also may pass into a condition which permits of its re-arrangement within the rock, C remaining still unaltered. A gradual fall of temperature now permits C to impress its form upon B as crystallization follows; and in its turn, A, being the last to consolidate, is moulded ophitically around both of its associates.

This is a necessary consequence of crystallization following a gradual increase of temperature which falls short of the degree requisite for the fusion of the most refractory minerals in a rock compound. It may come into play as much in a rock heated by contact metamorphism as in one whose temperature is raised by dynamic causes. I have in mind some cases I have lately seen in which thick piles of pyroxene-labradorite rocks, which were originally lavas, dykes, and sills, have been invaded by extensive protrusions of rocks of acid composition at some period subsequent to the outpouring of the lavas. The result, it appears to me, is that the parts of the lavas which were the last to consolidate from the original molten condition, that is to say, the glassy magma and the pyroxenic constituents, were afterwards fused again in the reverse order of their original cooling, as the temperature of the invading mass began to affect that of the older volcanic rocks around it. But as the melting point of both the felspars and the remaining rock constituents was never reached during the invasion, these minerals remained as they were. Eventually the temperature declined, the pyroxene and the minerals composing the original glassy magma crystallised out, and, around the contact zones, the lavas, dykes, and sills reconsolidated as holocrystalline rocks with ophitic structure, and with a plutonic instead of volcanic facies.

Analogous changes to these must, I conceive, frequently have taken place in connection with rocks undergoing plutonic metamorphism; only in these cases the partial rearrangement of the constituents was due to the heat generated directly by dynamic causes, and as a consequence of the gradual and partial relief of pressure while the rocks in question were in a potentially molten condition.

The nature of the minerals resulting from any given change of this kind is absolutely dependent upon the nature of the constituents present within segregating distance of the zones affected. If, for example, alkalies are deficient during any given stage of metamorphism, neither the felspars, nor any other mineral into whose composition the alkalies enter, can result. This has always been the great stumbling-block in the way of those who have attempted to account for the origin of gneiss, for example, from metamorphosed sediments. It is certain, from the very nature of the case, that the alkalies must have been removed from the constituents of the sedimentary rocks long prior to the date of their rearrangement in a stratified form. It has very properly been objected to the extreme views held by metamorphists that no kind of fusion or rearrangement of any kind is competent to metamorphose an ordinary greywacke into a granite, for the simple reason that the most important constituent of one of the essential minerals of the granite, to wit, the potash of the felspars, did not originally occur in the material acted upon. Yet the study of highly metamorphosed rocks whose sedimentary origin is beyond a doubt, shows that, by some means or other, secondary felspar has been formed within such rocks, and in those in which the effects of dynamo-metamorphism has been carried

to an extreme, felspar in a crystalline form has begun to develop in conspicuous quantities. In other words, a rock that was originally deficient in potash is known to contain a considerable percentage of that alkali after the rock has been subjected to dynamo-metamorphism. Now, as the presence of crytalline felspar is an essential feature in gneiss as well as in granite and other rocks, it becomes a matter of considerable importance to determine the source of the potash and other alkalies in question. Unfortunately the evidence available as yet is but scanty, and will hardly suffice for more than a working hypothesis such as that here propounded :—

When an eruptive rock, such as granite, is exposed to the action of surface agencies, its constituents, as Mr. Teall remarks, eventually became separated into an insoluble and a soluble set. The first goes to make up sandstones and shales, etc., while, in a soluble form, the alkalies are carried away by running water. Part of the alkaline matter goes into the soil, whence some of it is re-extracted by plants. Whether the whole of it does so is certainly open to question. It is far from unlikely that small percentages are carried downward through the soil by percolating water, and are eventually returned to the inner zones of the earth's crust, whence they originally started. The remainder of the alkalies, not absorbed by the earth, is carried out to sea, into which rivers are, and have always been, pouring considerable quantities of both potash and soda, etc., which have been set free from the surface of the land by weathering. What becomes of all this alkaline matter? The sun's heat distils only fresh water from the surface of the ocean, leaving its dissolved salts behind. Unless there are some agencies at work using up the alkalies as fast as they arrive, they must go on accumulating, and the balance of nature eventually be disturbed in this matter. Algæ take up some of the potash; but algæ die in the water, and so restore to the sea what they have originally taken from it. Glauconite and other minerals containing potassium compounds may use up another part. But even these remain where they were formed. Is it not more likely that both potash and soda in small quantites are slowly returning to the inner zones of the earth's crust by downward percolation from the surface of the land and the bottom of the sea? The quantity may not be great at any given period; but great geological results more often ensue from comparatively feeble causes acting through long periods of time than from those of a more energetic character.

Downward percolation from the surface of the land and the bottom of the sea may not be the only source of the alkalies required for the regeneration of felspars. At the high temperatures prevailing where rocks are undergoing plutonic metamorphism, what can be more likely than that emanations of both potassium and sodium in some mobile form should arise from the metallic zones of the earth's crust, and thence permeate the heated rocks within range of their influence? For several reasons I am disposed to regard this as the chief source of the restored alkalies, and to consider such intromissions an essential factor in the conversion of metamorphosed

rocks of sedimentary origin into their succeeding plutonic, trappean, and volcanic forms.

Once these constituents are restored to the rocks undergoing plutonic metamorphism, the regeneration of the felspar ensues almost as a matter of course; and it is difficult to see what there is to limit its development except the quantity of silicate of alumina already existing within the rock, and the percentage of matter subsequently introduced from without.

It appears that the earlier stages of development of the felspar take the form of isolated granules occurring interstitially amongst the other constituents, and are contemporaneous with the development of granulitic structure. Subsequently, a further development takes place along the planes of structural weakness as the pressure is gradually relieved, and the felspar takes the form of augen.

Development of felspar does not end with the formation of isolated augen; for although the typical and the commonest occurrence is that of eyes consisting of single individuals, it is by no means uncommon to find small nests collected at particular centres, which, in this case, as in the other, evidently mark the points where there has been a local relief of pressure during one of the thrusts. From small knots or nests of this kind every gradation can be traced into those remarkable aggregations of rock-forming silicates to which the term pegmatite is generally applied. True pegmatites, as here understood, are generated within the rock, their constituents graduate interstitially into the parent mass, and in every case they date from a period in the history of the rock long subsequent to that of its consolidation. In their composition and their general aspect pegmatites may agree with certain "giant granites," and both pegmatite and "giant granite" agree in the fact that they are usually coarser parts of the parent mass, that they are related to this in mineral constitution, and that they graduate into it, so that the line of demarcation between the later rock and the earlier is indefinite in both cases. But "giant granites" are contemporaneous with the last stages of consolidation of the rock in which they occur, and are confined exclusively to plutonic rocks; whereas pegmatites are of much later date than their host, and they occur exclusively in rocks that have undergone more or less deformation by plutonic causes at a period anterior to their development. From intrusive veins they differ in the important fact that in many cases it can be shewn that they both originate and terminate as augen do, within the enclosing rock, instead of being offshoots of larger plutonic masses adjoining, which is necessarily the case with an intrusive vein.

Pegmatites, like their component augen, appear to be generally formed along pre-existing planes of structural weakness, as it is along such planes that relief of pressure most commonly ensues as a consequence of lateral thrusts during the upward phases of terrestrial undulations. Hence pegmatites shew a marked tendency to run in rudely parallel zones, which conform to the planes of schistosity, or to any other pre-existing planes of structural weakness existing at the time.

Pegmatite bands develop in increasing proportion as we approach the zones of maximum metamorphism, so that, where their development has proceeded to any great length, they impart to that particular zone of rock the appearance of bands of crystalline felspar, etc., graduating at their sides into other bands, which consist of more or less distinctly granulitized schist. A closely-welded rock compound of that nature is, in all essential respects, a truly foliated rock, and it is difficult to state in what respect it differs from many rocks that are comprehended under the term gneiss.

In other words, granulitic structure develops into augen; augen extend until they pass into pegmatite; pegmatites aggregate until they impart to the compound, of which they form a part, the character of a true gneiss.

Augen structure in rocks is, according to this view, one of the earlier modifications whose later developments lead, in the one direction, into the rocks of eruptive origin, and, in the other direction, into truly foliated rocks, such as gneiss. The difference in the final result in either case is due to the mode in which the relief of pressure acted upon the rocks while they were in potentially molten condition, arising from dynamic causes. The pressure was relieved abruptly, and entirely, in the case of the eruptive rocks, and by very slow degrees and, only partially, in the case of the foliated rocks.

This view of the origin of certain gneisses by dynamo-fusion does not preclude the adoption of the theory of the formation of other gneisses by differential movements acting upon an igneous mass in its later stages of original consolidation. This is so evidently the mode of origin of many undeformed gneisses that I have for some time past employed for different types of original gneiss such names as granite gneiss, granitite gneiss, syenite gneiss, diorite gneiss, gabbro gneiss, etc., to express this fact. Nor does it preclude the possibility of some forms of gneiss having originated in any other manner not here referred to. Nevertheless, I venture to submit that this view of the common origin of certain eruptive rocks and gneisses by means of variations in the relief of pressure upon superheated masses may fairly claim to rank as a useful working hypothesis, seeing that it enables us to account for the intimate association, on the one hand, of gneiss with true schists, and on the other with the eruptive rocks, both plutonic and volcanic; and also that it presents a satisfactory explanation of the intimate association of gneisses with the deeper-seated cores of mountain ranges, of whatever age, or wheresoever situated.

V.—On the Three Glaciations in Switzerland.

By C. S. Du Riche Preller, M.A., Ph.D., A.M.I.C.E., M.I.E.E., F.C.S., F.G.S.

UNTIL very recently it was thoroughly recognised that in post-Tertiary, viz., Pleistocene or Diluvial times, there occurred in Switzerland, as elsewhere, two glaciations which covered the Alps and the greater part of the Swiss lowlands, and between

which intervened a genial or interglacial period. The repeated advance of Swiss glaciers was first established by Escher von der Linth and Heer, more especially upon the evidence of the lignite slate deposits near Durnten and Wetzikon, which fringe the edge of what was at one time the Limmat and is now the Glatt valley, to the N.E. of Zurich, and were formed during the interglacial period referred to. But since Prof. Penck and others have been led, on the strength of fluvio-glacial evidence, to recognise in the Bavarian and Austrian Alps not only two, but three, alternately recurring glaciations, evidence to the same effect has, within the last two years, been brought forward also in Switzerland, more especially by Dr. Du Pasquier; and as the district of Zurich, owing to the building operations and public works constantly in progress, abounds, perhaps more than any other part of Switzerland, in quarries and excavations of all kinds, I recently took occasion to examine in this locality various glacial deposits, which may be taken as typical examples of the successive glaciations.

Introductory.—Before dealing with those glacial deposits, it will be convenient to briefly refer to the molasse and nagelfluh formation which immediately preceded the glacial epochs. The Miocene molasse formation, composed of mud, clay, and sand, which was derived by denudation from the younger rocks of the Central Alps and hardened into marl, limestone and sandstone, spread more or less over the whole of the Swiss lowlands, and formed a flat freshwater basin, with a sub-tropical flora and fauna and a mean temperature which, according to Heer's calculation, was 18·5 degrees Centigrade (68 F.) or more than double that of the present mean temperature of 9° Centigrade or 48° F. This molasse basin was subsequently filled up and more or less completely covered by that characteristic fluvial conglomerate known as nagelfluh, whose pebbles were derived chiefly from the detritus of the Central Alps. The nagelfluh in the Canton of Appenzell, in the north-east corner of Switzerland, contains pebbles derived from rocks which do not now exist on the northern slopes of the Alps, but are related to rocks such as occur in Southern Tyrol at Botzen, at Lugano and elsewhere on the southern slopes. This fact led Prof. Heim to argue that those pebbles are derived from what are now the Southern Alps, and that the crest line of the Alps was at one time much more to the south than it is now. That in some parts the divide of the two main watersheds may have been somewhat more to the south is not improbable,[1] and that the upheaval of the Alps brought about important deflections of river courses is certain; but there is no reason why such rocks as those of Botzen and Lugano should not have existed also more to the north, whence they were washed away by the Alpine rivers and their débris were deposited as pebbles of the Miocene

[1] In a recent paper "On the Engadine Lakes" I showed—and this is also Prof. Bonney's and Prof. Heim's view—that the crest line of the old Inn watershed was about six miles more to the south than it is now; but on Prof. Heim's theory the crest line of the Julier Alps and Hinter-Rhine watershed, if placed in a line with Lugano and Botzen, would have been 35 miles further south than it is now, a conjecture for which there is no evidence.

nagelfluh. Upon the sub-tropical molasse age, essentially one of slow accumulation and spreading of clay, sand, and mud, followed in early Pliocene times the formation of the Alpine and sub-Alpine valleys, partly as the effect of thrusting, folding and upheaving of the Alps, partly by the action of Alpine rivers, whose erosive power had become greatly enhanced by the greater fall of the upheaved, and, moreover, more or less denuded Alpine slopes. It may, therefore, be assumed that by the end of this Pliocene period of erosion, as distinguished from the Miocene period of accumulation, the Alps and the principal Alpine, as well as sub-Alpine, valleys presented, broadly speaking, the general outlines which they exhibit now.

First Glaciation.—The valley-making of Pliocene times was accompanied by a gradual drop of temperature, due probably to an increase of precipitation, viz. of snow and rainfall in the Alps raised considerably above their former level; and so great was this climatic change that the latter part of the Pliocene age was marked by a general advance of the Alpine glaciers and a first glacial invasion of the Swiss lowlands. This first glaciation of Pliocene, viz. Tertiary age, is evidenced by the so-called hollowed-out or "löcherig" nagelfluh, which is quite different and distinct, not only from the molasse or Miocene conglomerate bearing the same name, but also from the gravel deposits of subsequent glaciations. The qualification of "hollowed-out" (löcherig) was first given to this nagelfluh by Escher von der Linth, owing to the holes left in the clayey and calcareous cement by pebbles which had been decomposed and washed out by chemical action. Mousson, Escher von der Linth, and Gutzwiller recognized it as a glacial deposit much more recent than the molasse. Wettstein, writing in 1885,[1] did the same, but included it in the later (then first) glacial period; Prof. Heim, as recently as 1891,[2] speaks of it tentatively as perhaps belonging to an older glaciation. But as early as 1885 and 1886, Prof. Penck[3] and Prof. Brückner[4] had recognized three distinct glaciations in the Bavarian and Austrian Alps, and had pointed out the close analogy between the "Deckenschotter" or sheet-gravel of those Alps, and the Swiss fluvio-glacial deposits;[5] and it was not till quite recently, viz. 1891–92, that Swiss geologists, and first among them Dr. Du Pasquier, took the plunge and adopted the same view. Of the various deposits of this Pliocene nagelfluh which I have examined, there are more especially two very instructive ones, one on the Utliberg near Zurich, and the other near Baden, about fourteen miles below Zurich. As is seen from the diagram, the summit of the Utliberg is formed by Pliocene hollow nagelfluh, which rests on moraine or boulder-clay, and this in its turn rests unconformably on Miocene molasse and nagelfluh. An erratic block of Miocene nagelfluh, which was found in 1883 imbedded in the moraine and below the hollow nagelfluh,

[1] A. Wettstein, "Geologie von Zurich und Umgebung, 1885." This gifted young geologist lost his life on the Jungfrau.

[2] Naturf. Gesells. Neujahrsblatt, 1891.

[3] Vergletcherung der Deutschen Alpen, 1885; Der Alte Rheingletscher, 1886.

[4] Vergletcherung der Salzach Gebietes, 1886.

[5] Fluvio Glaciale Ablagerungen der Nordschweiz. Geol. Karte Schweiz, 1891.

is still preserved on the Utliberg. This moraine, which is much older than the moraine on which the town of Zurich is chiefly built, passes gradually into moraine sand or surface moraine; and this again passes into hollow nagelfluh, which forms a cap with perpendicular sides from 60 to 100 feet in depth. The superposition referred to is exceedingly characteristic, and leaves no doubt whatever as to the fluvio-glacial origin of the hollow nagelfluh, viz. as having been deposited, not by the glaciers themselves, but subsequently by the streams emerging from them, and following, in the main, the lines of the moraine deposit. The occurrence of this Pliocene nagelfluh at such an altitude of 872 metres (2880 feet) above sea-level, or 460 metres (1520 feet) above the present level of the Limmat valley at Zurich, led Prof. Heim and also Prof. Muhlberg, an authority on the glacial deposits of the Aare Valley, to conjecture that that nagelfluh had been deposited by a stream flowing at that altitude between the glaciers of the Zurich and Zug valleys;[1] but the occurrences of the same Pliocene nagelfluh not only on the other side of the Zurich lake, but throughout the north of Switzerland, in a line between Zurich and the Rhine, clearly show, as Dr. Du Pasquier also points out, that it is not a local fluvio-glacial deposit, but forms part of the Swiss Deckenschotter as a whole.

The deposit near Baden is to be found in a ravine locally called the "Teufelskeller," situated at about 470 metres above sea-level, viz. about 1300 feet lower than the summit of the Utliberg. It constitutes perpendicular banks thirty to a hundred feet in height, and shows all the characteristics of the Utli deposit, which by the much larger rounded off pebbles and the extremely hard cement consisting of thin calcareous films or skins, distinguish it from the younger fluvio-glacial gravel deposits of the Limmat valley. In this occurrence its composition is more or less uniform, and the banks descend too much below the surface of the ground to show either the moraine or the molasse on which it rests; but on the other side of the same hill there is a quarry about 40 feet in vertical depth, which is not mentioned in Dr. Du Pasquier's admirable work, and in which I found distinct evidence of the hollow nagelfluh becoming towards the base of the quarry gradually a finer and looser conglomerate, and passing into sand and surface moraine as shown in the diagram. The principal constituents of the hollow nagelfluh are here, as on Utliberg and elsewhere, quartzite,

[1] Prof. Heim, Neujahrsblatt, 1891. Prof. Heim argues that the glaciers preserved the Limmat and other lake valleys from being choked up by surface moraine, since they carried it on their backs and thus served as a bridge. But these valleys must have been, and were, filled up to a considerable extent by ground moraine, part of which was subsequently again removed by fluvial erosion. Judging from the depth at which the ground moraine must have been deposited at the bottom of some of these preglacial or Miocene valleys, and the altitude at which sheet-gravel is found (3300 feet above sea-level at the Bachtel east of Zurich, and 3500 feet near Bregenz on Lake Constance), the glaciers must in many places have reached a thickness of 2000 feet and more. Above Amsteg, in the Reuss valley, the glacier scratches reach up to 6600 feet, and in the Rhone valley (Canton Vaud) even up to 11,000 feet altitude above sea-level.

hornstone, nummulitic limestone, dark Alpine limestone, derived from the detritus of Miocene nagelfluh, red limestone or sernifite, green or so-called Tavayanaz sandstone, and other rocks of the Glarus Alps. Pebbles of Julier and Puntaiglas (Rhine watershed) gabbro, granite, and diorite which abound in the later glacial deposits, are absent in this nagelfluh: hence the inference that its constituents are derived exclusively from the Glarus Alps.[1] Some other very large deposits of hollow nagelfluh occur in the Aare Valley and below Turgi, near Kaiserstuhl on the Rhine, and on the Irchel, bordering on the Rhine and situated about half-way in a line between Zurich and Schaffhausen. The deposits named, together with other intermediate ones, vary in altitude above sea-level from 300 to 872 metres or, roughly, from 1000 to 3000 feet, thus forming a belt of fluvio-glacial deposit, which may, therefore, be also taken as indicating the contour line and limit of the terminal moraine of the first Upper Pliocene glaciation.

Second Glaciation.—Upon a long interglacial Upper Pleistocene period of erosion, followed a second and far more extensive glaciation, which covered the whole North of Switzerland to Basle and the Jura, while to the south-west the Rhone glacier advanced as far as Lyons. Of the glacial deposits of this period I examined, among others, the very typical deposit laid open in a quarry on the so-called Allmend of Zurichberg, viz. on the hill above the town, on the right of the lake and opposite Utliberg, at an altitude of about 570 metres or 1890 feet above sea-level. In this deposit the boulder-clay, showing the usual characteristics of larger and smaller more or less angular blocks with polished and striated surfaces, passes gradually into gravel-bearing moraine sand or surface moraine, which, in its turn, is covered by a thin layer of alluvial soil. This gradation, shown in the diagram, is observable in every one of the numerous smaller quarries, excavations and foundations for building purposes on the Zurich hills flanking the lake on the right bank, seeing that these hills are entirely covered with the deposits of the second glaciation resting on molasse. The gravel-beds of the Limmat valley, which are so extensively quarried below Zurich, and reach as far as Turgi, Waldhut, and Basle, are the fluvio-glacial deposits of this second glaciation, and the characteristic feature of all the three gradations, viz. of boulder-clay, moraine sand, and the glacier-stream deposits, is that their material is largely derived from rocks of the Grisson Alps, such as granite and Marmels gabbro[2] of the Julier Alps (Hinter-Rhine) and of Puntaiglas granite and diorite (Vorder-Rhine), showing that in Middle Pliocene times there existed a connection between the Rhine and Linth valleys and that the glaciers of the former considerably reinforced those of the latter.

[1] Puntaiglas granite and diorite are derived from the classic locality or valley of the same name, descending from the southern slopes of the Tödi group to the Vorder-Rhine valley near Truns. Sernifite is a red limestone derived from the Sernf valley in the Glarner Alps from Glarus to Elm.

[2] Marmels gabbro is derived from the classic locality of that name, situated in the Oberhalbstein or Sur valley (Julier Pass) of the Grisson Alps.

Third Glaciation.—The enormous second glaciation, during which the North of Switzerland must have presented an appearance similar to that of Greenland at the present time, was followed, after another interglacial (Middle Pleistocene) period, by the third glaciation, the last of diluvial times. Among the deposits of this last glaciation are those on the low range of hills on the left bank of the lake above Zurich, and here I examined more especially the extensive quarries on the summit of the ridge and near the Froschen-lake, close to the high road which connects Thalweil (on the lake) with Gattikon (in the Sihl Valley). In these quarries (540 metres or 1780 feet above sea-level) the moraine sand and boulder-clay reaches 30 to 60 feet in depth. The deposits consist largely of calcareous and also siliceous sand, bearing a great many large angular blocks, together with smaller ones, partially rounded-off, polished and striated. The deposits in the mounds overlying the gravel beds of second glaciation near Killwangen, between Zurich and Baden, which I also examined, present similar features, but the characteristic feature which distinguishes all these deposits from those of the second glaciation consists in the blocks and pebbles, viz. grey, red, and black limestone, green sandstone with black spots, derived exclusively from the Glarner Alps, viz. from the Linth watershed, the granites and other rocks of the Julier Alps and the Vorder-Rhine, viz. of the Rhine drainage area, being entirely absent. This fact affords substantial proof that in Upper Pleistocene times, viz. at the time of the third glaciation, the connection between the Rhine and Linth systems was already severed by the saddle thrown up by the Setz and Tamina at Sargans. The Linth glacier, properly speaking, did not advance beyond Baden; on receding it halted at Killwangen, and subsequently was for a long time stationary near Zurich, as evidenced by the terminal moraine walls which are so characteristic of that town.

Conclusion.—After the great folding, thrusting, and raising of the Alps in Miocene and Pliocene times, coinciding with the formation of the principal Alpine valleys, and accompanied by great climatic changes, we have, therefore:—

(1) A first glaciation and filling up of the valleys by glacial deposits, the limit of glaciation or terminal moraine in the North of Switzerland being a curve between Zurich and the Rhine at Kaiserstuhl and Irschel, and the axis of the main glacier pointing in the direction of Waldshut, the present confluence of the Aare and Rhine systems.

(2) A second glaciation, which, in the North of Switzerland, spread to the foot of the Jura, to Basle, and the Rhine.

(3) A third glaciation, which did not spread beyond the limits of the first, viz. to within 10 miles below Zurich on the one hand, and to the Rhine as far as Schaffhausen on the other, while the tongues of the Reuss glacier advanced to within about six miles of Turgi and Aaran, the Aare glacier to within ten miles of Olten, and the northern tongue of the Rhone glacier extended along the base of the Jura to about four miles beyond Soleure in the present Aare valley.

The general limit of this last glaciation in the North of Switzerland would therefore be indicated by a curve from Schaffhausen to Zurich and Soleure.[1]

Upon each of these periods of filling up, there followed an interglacial period of erosion, during which the rivers swept away and carried towards the sea the greater part of the accumulated glacial deposits. The first of these interglacial periods must have been very long and the erosive action very powerful, seeing that in the North of Switzerland the belt of hollow nagelfluh and isolated occurrences of moraine, such as that of Utliberg, are the only surface remains of the vast amount of material which the first Pliocene glaciation deposited, both through direct and through fluvio-glacial action. The second interglacial period was of much shorter duration; Heer estimated it at 6000 years; but it lasted at any rate long enough to produce the lignite deposits near Durnten, Wetzikon, Uznach, and Rorschach and the similar lignite bands near the Lake of Thune, which escaped or resisted the erosive action of the old Linth and of the Kander respectively; and, together with the débris-cone in the Lorze valley near Zug, constitute indisputable evidence of that second interglacial period.[2] The third period of glaciation and filling-up was succeeded by our own alluvial time, which is again a period of active erosion. This is evidenced by such rivers as the Rhine, the Aare, and the Limmat, of which the former has at various points eroded all the successive glacial and fluvio-glacial deposits[3] down to the solid rock, and has thereby

[1] Broadly speaking, the three glaciations are typically represented in the Zurich District by the three ranges of hills running parallel to the lake, viz.:—

1st	glaciation,	moraine of	Utliberg or Albiz range, mean altitude	2600	feet.
2nd	,,	,,	Zurichberg ,, ,,	1800	,,
3rd	,,	,,	Gattikon hills, and belt of moraine walls in Zurich ,,	1500	,,

above sea-level, or 1150, 450, and 150 feet above lake-level respectively. In all cases, the moraine rests on molasse. Quite recently I had occasion again to examine these deposits in the company of Prof. Bonney.

[2] Among the deposits of the second interglacial period should be further noted the "Löss," viz. the fine sand and loam which occurs extensively along the foot of the Jura, as well as in the Rhine valley near Rhinfelden and Basle, and also in the Aare valley near Aaran, and again near the confluence of the Aare and the Rhine, and generally rests on the fluvio-glacial deposits of the second glaciation. By some geologists this Löss has been held to be simply mud, deposited by rivers when in flood; by others as the product of chemical metamorphism; and again by others, such as Professors Richthofen and Muhlberg, as of Æolian origin, viz. as blown sand, this latter theory being the one now in vogue. Further interglacial evidence is afforded by the so-called lake-chalk of Zurich, viz. the chalk which separates out of the lake water, and a deposit of which was found in the bed of the Limmat at the lower end of the lake, between the moraine of the second and third glaciations.

[3] The fluvio-glacial deposits or gravel-beds of the second and third glaciations, which in the North of Switzerland extend along the principal rivers to their confluence with the Rhine, and thence and beyond to Basle, are called by Dr. Du Pasquier the Upper-Terrace and Lower-Terrace Gravels respectively. The moraines of the second and third glaciations are called by Swiss geologists the "outer" and "inner" moraines respectively; Dr. Du Pasquier, in deference perhaps to these time-honoured designations, and also to those of "first and second glacial periods," or "last" and "penultimate" glaciation, terms the Pliocene (hollow nagelfluh) glaciation the "old" glacial period; I have called them simply first, second, and third glaciations.

produced the rapids of Kaiserstuhl, Laufenburg, Rheinfelden, and others, while similarly the Aare has in various places, *e.g.* at Brugg and Laufthor, eroded the gravel and moraine of the three glaciations down to the molasse, and the Limmat at Wettingen below Zurich, and again between Baden and Turgi near its confluence with the Reuss and Aare, is now eroding the molasse itself.

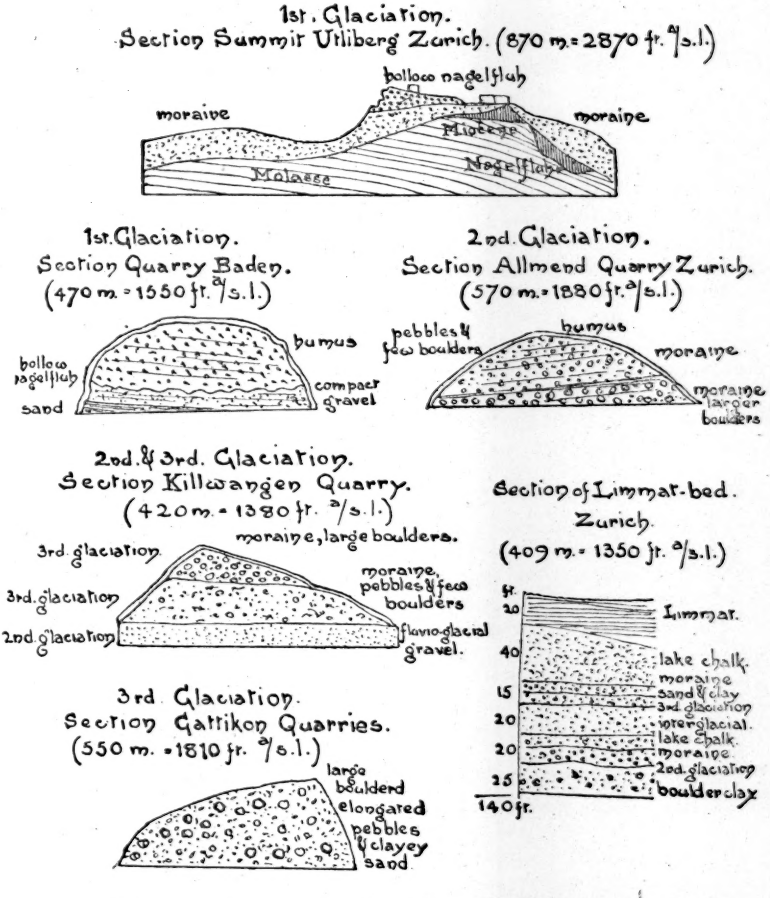
The following Table shows at a glance the succession and extent of the three glaciations:—

Interglacial?	Alluvial	Present time	Erosion of valleys	Peat-moors on ground moraine.[1]
Third Glaciation	Upper Pleistocene		Filling-up ,,	Terminal moraine: Schaffhausen, Zurich, Soleure.
Second Interglacial	Middle Pleistocene		Erosion ,,	Interglacial lignite deposits: Durnten, Kander, Zurich lake chalk, Lorze débris-cone Löss.
Second Glaciation	Middle Pleistocene	Diluvial	Filling-up ,,	Terminal moraine: Schaffhausen, Basle, Jura.
First Interglacial	Lower Pleistocene		Erosion ,,	(Formation of Alpine lakes.)
First Glaciation	Upper Pliocene		Filling-up ,,	Terminal moraine: Schaffhausen, Zurich, Soleure.
Nagelfluh and Molasse	Lower Pliocene / Miocene	Tertiary	Erosion ,,	(Formation of Alpine and sub-Alpine valleys.)
			Filling-up ,,	(Sub-tropical fresh water basin.)

As regards, in conclusion, the question whether we live in another genial interglacial period, and have to face the contingency of a further recurrence of glaciation and of a refilling of the valleys following upon the present period of erosion, that contingency is not nearly so remote as might appear. During the present century the Alpine glaciers have shown considerable fluctuations. In the first quarter of the century, they steadily advanced, and this advance reached it maximum between 1820 and 1830. They then receded, but after various fluctuations advanced again between 1850 and 1860. Then followed another period of shrinkage, the glaciers reaching a minimum in 1880, since which time there has been a fresh advance at an ascertained average rate of 100 metres or about 330 feet per annum, say one foot per day. These fluctuations are easily accountable when we consider that the mean annual temperature within a given district or watershed not infrequently varies as much as 3° C. or about 6° F. in consecutive years, and that a decrease of

[1] Peat-moors, such as those in the Glatt valley N.E. of Zurich and on the hills (Zurich berg) which separate that valley and the lake of Zurich, are always an infallible criterion of ground moraine underlying them. This ground moraine or boulder-clay generally rests on the bottom of pre-glacial molasse valleys; it offers great resistance to the percolation of water and even to fluvial erosion, and remains compact. Hence the soil overlying the boulder-clay does not favour cultivation. Surface moraine or moraine sand, on the other hand, is highly conducive to vegetation, owing to its permeability and the consequent decomposition of alkali producing vegetable matter.

only 1° C. is sufficient to cause the snow-line to descend about 300 feet while the glaciers advance, unite, and spread at a much more rapid rate. A gradual drop of the present mean temperature of sub-Alpine Switzerland of 2° C., viz. from 9° to 7° C. would suffice to bring the glacier-terminals from their present mean level of 3800 feet down to 2800 feet, and a further drop to 4° C. or 39° F. would bring them again to the level of the lakes of Constance, Zurich,



Lucerne, Thune, and Geneva. But climatic changes of such comparative magnitude, so far as they are dependent on purely local phenomena, could only be brought about by a new gradual upheaval or upward thrusting of the Alps, which would largely increase the area, and therefore the quantity of precipitation; in the meantime, there is now indisputable evidence of three glaciations having already taken place. Sufficient unto the day is the evil thereof.

VI.—Notes on the Composition of Clays, Slates, etc., and on Some Points in their Contact-Metamorphism.

By W. Maynard Hutchings, Esq.

MR. TEALL, in his very interesting and suggestive address to the Geological Section of the British Association at Nottingham, alluded to the composition of sediments (clays, etc.) as compared with that of older sedimentary rocks, and specially to the amount of alkali contained in them.

At the time he made his remarks I was engaged on some analyses of clays, with a view to gaining information on this particular point, in connection with studies of clays and slates which I have been carrying on for some years, and on which I have published papers in this Magazine on former occasions. The results of these analyses, and some considerations arising out of them, I propose to give as the first item of these present "notes."

For reasons which I stated on a previous occasion, I have taken for special study the series of clays and shales which occur in the Coal-measures, and of these I have used for detailed microscopical examination only such occurrences as were *not* in contact with Coal-seams. I did this because, wherever a bed of clay or shale has had a seam of Coal immediately above it, we may assume that it has served as the soil on which the vegetation grew which produced the Coal, and has thus been deprived of large amounts of alkali, and so altered in its chemical composition in a manner which would not apply to quite similar deposits of sediment in other formations. Also beds of clay and shale occurring with Coal are often broken up,—are unstratified,—and so affected mechanically as well as chemically, and rendered less suitable for the observations I had in view.

I have always maintained, and still maintain the more strongly the more I examine them, that the clays and shales of the Carboniferous beds represent the waste of granitic or gneissic areas practically "pure and simple," and that they are in all respects the counterparts of the sediments which gave the materials for the principal masses of slates and slaty grits of the older geological formations. But there was always an apparent *chemical* difficulty in the way, inasmuch as the published analyses of these carboniferous clays showed so little alkali that they could not be supposed capable of yielding slates of average composition unless some means were assumed by which alkali could be added, and no such means could be suggested for which there is any evidence. This difficulty was also pointed out to me by others, among whom was my friend Mr. Teall himself.

I was convinced from microscopical work, levigations, etc., that in the clays examined there was much more potash-mica than would be represented by the alkalies usually reported in the analyses on record. In considering these analyses several points must be kept in view. For one thing, just the clays which I avoided as being *abnormal* from a geological standpoint are those of most industrial importance, and therefore most analysed; a clay being usually a better "fireclay" the less alkali it contains. Then again, many of the analyses are

old and were made when the determination of alkalies was not so easy and so accurate as it has been since the Lawrence Smith method came into general use. In many analyses, again, alkalies were simply determined "by difference," and the figures are worse than useless. In many other cases potash only is given, and it is not too much to say that many "technical" analyses are not carefully enough made to render them available for scientific purposes.

It would not serve any useful purpose here to quote a large number of analyses of "fireclays," but the following figures may be of interest. They give the average percentages of silica, alumina, and potash in a series of eight analyses made by Mr. E. Riley on clays from the Dowlais Coal-field. Mr. Riley's name is an assurance of the accuracy of any analyses made by him :—

	Silica.	Alumina.	Potash.
Maximum	67·12	34·76	4·19
Minimum	44·25	21·18	1·21
Average	53·39	28·91	2·11

It may be remarked that Mr. Riley has not determined soda, though this is present in all fireclays,—according to my own examinations being usually about one-fourth of the amount of potash. Moreover, the average amount of water and organic matter in the above analyses was 11·63 per cent. The loss by ignition of an average slate is about 3 per cent. only, so that for purposes of comparison the alkali in the above figures would have to be increased about 8 per cent.

I have made with the greatest care a series of six analyses. For this purpose I used the material in my possession in the form of a number of cores from a bore-hole put down in the Coal-field at Aspatria, near Carlisle. The bore-hole was 800 feet deep, and the specimens represent various beds of sandstone, shale, and clay, with the gradations between them. For microscopic examination I have made sections of this material from eighteen different points.

The analyses of the sandstones and very quartzy clays and shales would have no special interest. I have selected samples of very fine-grained clay representing beds at various depths from 330 feet to 685 feet, and one bed of more quartzy material. None of these were in contact with Coal. The clays are very compact and hard. Ground with water they are exceedingly plastic.

No. 1 contains a good deal of quartz, which is seen under the microscope as evenly dispersed grains. Nos. 2–6 are among the finest-grained clays I have seen. The quartz present is so finely divided that it cannot be detected at all among the mica, etc., in slides, and can only be found by levigation. No felspar can be detected at all. They are the most completely micaceous samples in my possession, and it is safe to say that very nearly all this mica is newly formed *in situ*.

The analyses were made on samples dried at 220° F.

Titanic acid has not been determined, and is therefore contained in the silica and the alumina of the analyses. Taking the careful research of Mr. Riley on the presence of titanic acid in clays as a

guide, we may reckon its amount as rather over 1 per cent. Its determination was not important for the purpose of these analyses. The iron present is all given as ferric oxide, though a small part of it is in the state of ferrous oxide. This partly causes the excess in the analyses. Traces of phosphoric and sulphuric acid, etc., have not been determined. From these analyses it will be seen that these clays would be capable, chemically considered, of transformation

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Silica	66·30 p.c.	59·28 p.c.	56·85 p.c.	59·25 p.c.	53·57 p.c.	54·46 p.c.
Alumina.....	18·95 ,,	21·85 ,,	24·58 ,,	21·93 ,,	24·53 ,,	23·75 ,,
Ferric Oxide	4·35 ,,	5·80 ,,	5·30 ,,	5·65 ,,	6·51 ,,	6·80 ,,
Lime	0·60 ,,	0·45 ,,	0·52 ,,	0·55 ,,	0·76 ,,	0·85 ,,
Magnesia ...	1·04 ,,	1·24 ,,	0·94 ,,	1·42 ,,	1·81 ,,	1·78 ,,
Potash	3·18 ,,	4·13 ,,	3·78 ,,	4·21 ,,	4·34 ,,	4·54 ,,
Soda	0·54 ,,	1·18 ,,	1·44 ,,	1·08 ,,	0·97 ,,	0·89 ,,
Water.....	5·35 ,,	6·25 ,,	7·15 ,,	6·21 ,,	7·65 ,,	7·53 ,,
	100·31	100·18	100·56	100·30	100·12	100·60

into very typical "clay-slates." *Mineralogically* they *are* clay-slates, having already undergone all, or nearly all, the mineral changes requisite to constitute the normal (unaltered) slates. Nothing more is needed but physical changes, such as compacting, arrangement of mica in a plane, increase of *size* of mica, etc.

The analyses of slates are very numerous, and there is no need to burden this paper with a reproduction of them; but, for comparison, I have taken, at random, eight analyses given by Roth in his "Allgemeine Geologie," 1890, among a list of analyses of slates from various parts of Europe.

	Silica.	Alumina.	Potash and Soda.
Maximum	65·84	27·93	6·06
Minimum	50·01	17·10	3·26
Average	57·93	22·76	5·07

Or again, taking nine analyses given in Renard's work on the slates of the Ardennes, the figures are—

	Silica.	Alumina.	Potash and Soda.
Maximum	61·57	31·95	6·07
Minimum	45·60	15·96	2·39
Average	57·20	21·87	4·36

It will be seen how striking is the approximation of the average figures of these seventeen analyses, and also how closely they agree with the average figures in the analyses of fireclays made by me.

Further, in making these analyses I had in view the question as to whether or not kaoline is present in these clays to any extent.

I have not been able to definitely satisfy myself by microscopic examination on this point, but have rather come to the conclusion that it is either absent or only very subordinate, and I think the analyses confirm this view, as regards these special samples at all events.

Seeing that no felspar is detected in them, we may assume that the

alkali present is combined in the very abundant mica, and we can calculate by Tschermak's formulae, as Renard does in his slate analyses, the alumina that would be required to form muscovite, with a proportion of paragonite due to the soda. If we do this, we find that the alumina required is respectively: No. 2=19·39 per cent., No. 3=19·54 per cent., No. 4=19·15 per cent., No. 5=19·04 per cent., and No. 6=19·29 per cent., leaving only 2·46 per cent., 5·04 per cent., 2·78 per cent., 5·49 per cent., 4·46 per cent., available for kaoline or any other combinations.

These figures are on the assumption that only the *alkali* is present in the mica, requiring alumina in proportion. But it is more than probable, as Renard considers, that part, at least, of the magnesia, and perhaps some of the lime, are also combined in this mica, in which case a good deal more alumina would be required, though this would be partly compensated, possibly, by the replacement of some alumina by ferric oxide. At any rate, these calculations are able to show that not very much kaoline can be present in these clays as they now are. And the evidence, chemical and microscopical, leads to the belief that, supposing kaoline formed a part of the original deposits, as it probably did, it was either sparingly represented or has been altered since. The same arguments, supported by analyses, apply equally to many slates in which no felspar can be detected, in which mica is the only mineral present which contains alkali, and in which very little alumina is available after calculating what is required for this mica.

Of course there is no doubt that there are clays, in the Coal-measures and elsewhere, whose analyses show that a great deal of silicate of alumina is present as such. Some of the "fireclays" are examples of this, owing to removal of alkali by vegetation from the original felspar, and perhaps also from the mica originally deposited. And there are *slates* of similar composition in the older formations. They are, however, few in proportion to what may be called normally composed slates.

The mistake is often made of speaking of clays as if they were largely, or mainly, composed of the *chemical* waste of felspars, and as if this must always be kaoline. As I have previously shown, an examination of any series of the gradations from fine-grained clays into shales and sandstones disproves this completely. There is a great deal of felspar present which has been brought down as such. A decomposing felspar will be more easily broken up by denudation, and with the products of decomposition there will be carried away the fragments of the mineral itself, together with other felspar fragments not necessarily from decomposing crystals. In the coarser parts of the deposits this felspar has partly survived; in the finer mud it has all passed into secondary products. We know, from the experiments of Daubrée and others, how rapidly and easily felspar is decomposed when in a very fine state of division. So far as I have been able to follow the subject, this decomposition, after deposit in these clays, leads to the formation of mica and not of kaoline. Continued attention, which I have paid to the alteration of felspar

in granites, and also in andesites and other rocks, confirms me in the opinion that there also, though both occur, micaceous decomposition is very much more usual than kaolinitic. And it is quite reasonable to suppose that when kaoline is deposited together with much felspar, biotite, muscovite, etc., the changes which afterwards take place, involving as they do a micaceous alteration of the felspar with liberation of alkaline silicate in solution, may effect a conversion of more or less of the kaoline into mica, a process chemically quite simple, and quite probable under the conditions of pressure and temperature we know to have existed.

The examination, microscopical and chemical, of the materials from this bore-hole has also been of interest as showing the very uniform conditions as to nature of deposit of this not inconsiderable thickness. It will be seen that the five seams of fine-grained clay, separated though they are by very much coarser beds, and deposited at what must have been good long intervals of time, yet show only comparatively small variations in composition.

On a future occasion I hope to deal with some of the more modern clays, having different compositions from those now under consideration, and I think also more or less different origins. Clays such as I allude to have not, I consider, played any noticeable part in providing the materials for the older slates and grits.

In the Geological Magazine for October, 1891, I contributed some "Notes on the altered Coniston Flags at Shap," in which, among other things, I dealt with the question of newly-formed felspar in these rocks and with the nature of the "clear spots" observed in them. To these two points I wish now to recur, having continued to study these special rocks at Shap, and also having paid much attention to similar rocks in general.

As regards newly-formed felspar at Shap, Harker and Marr, in their work on these rocks, had stated that they looked on its presence as probable, but they did not definitely assert it. I had made every effort to make sure on this point, but was obliged to state that I could not obtain any *proof*, by microscopic tests, of its presence.

I must now retract this and say that not only is new felspar present in these rocks, but that it is at some parts of the exposure very abundant in the "mosaic" which is well developed near the granite. This altered conclusion is due to some extent to the additional number of very thin sections examined, of which I have now a series from over twenty points along the limited exposure in Wasdale Beck; but is due much more to improvements in the appliances I have used. A few remarks on this subject may not be out of place here.

Everybody who has tried to do much work on *minute* mineral sections in convergent polarized light, using, say, $\frac{1}{8}$ inch objectives, knows what a terribly unsatisfactory thing even the best rotating stage is. It is not too much to say that "that way madness lies." I had a "Dick" microscope made for me by Swift and Son, fitted with a good condenser. The benefit of the change to this instrument can only be fully understood by those who have tried it; one

regrets every hour wasted in using the old rotating-stage horror! But the full advantage of the change for the special class of work in question was only realized when my friend Mr. Dick persuaded me to use a $\frac{1}{12}$ inch oil-immersion objective, a thing that would have been quite out of the question with the rotating-stage. The optic figures obtained by its use (of course in combination with a suitable condenser, and with a sufficiently small perforation in the diaphragm under the eye-piece) are quite good and certain where those got by means of a high-angled $\frac{1}{8}$ inch are too indistinct to be of any value, or where the mineral under observation is so small in area, and so thin in section, that the $\frac{1}{8}$ inch gives no figure at all.

Thus, these contact-slates have to be sliced extremely thin in order that there may not be any superposition of minerals, and in these very thin sections nothing but optic figures in convergent light can usually safely decide whether given grains of the mosaic are quartz or felspar, the felspar-grains being without cleavage.[1]

There are also very great advantages in using these lenses for other special purposes outside of the study of optic figures, as for the examination of minute structures, enclosures, etc. Those petrologists who are using these high-power immersion-lenses (there is no need to stop at $\frac{1}{12}$ inch) will, I think, fully concur in what I have said above, and in the desirability of encouraging their use by others who may still regard them as rather outside the requirements of the petrological microscope.

In the altered slates at Shap, then, felspar is plentiful. In some slides there appears to be almost as much felspar as quartz in the limpid mosaic. The grains of it, like those of the quartz, are rich in enclosed microlites and have frequently the more or less sharply bounded polygonal outlines so characteristic of both these minerals in fully developed mosaics of contact-rocks. This mosaic, or "tesselated" structure, when at its best, is so very like the cells of a honeycomb that in German literature it is frequently spoken of as "honeycomb-like." This is such a very good description of it that it is almost a pity the word is already appropriated among us for another meaning.

I have made the following two analyses to show the composition of the "flags" of Wasdale Beck. The same remarks apply here, as regards the non-determination of titanic acid, and the statement of all the iron as ferric oxide, as in the case of the analyses of clays already given:— (Analyses on p. 42.)

A is a sample of the rock exposed in Wasdale Beck, near the

[1] There is an appearance to be seen in these newly-formed felspars which is of the greatest diagnostic value. This is a peculiar striation, best seen in polarized light. It does not seem to be either a cleavage or a twinning. It appears to be peculiarly characteristic of felspar formed at contacts, and has been so noted by observers. It is duly emphasized by Zirkel in his latest volume. Unfortunately it is not regular in its appearance, and there are plenty of mosaics, especially those of smaller grain, with a good proportion of felspar, in which it is not seen. Where it does appear it may be relied upon as evidence at once. All grains showing it are felspar, and I have not come across any case where grains of this sort are seen in a mosaic, where a good deal of felspar is not also present in an unstriated condition.

hotel. It is a moderately altered slate, containing a good deal of quartz. Biotite has formed in considerable amount, but the quartz is still distinctly clastic. No sign of felspar is seen, and there are here no "spots." *B* is from a point about three-quarters of a mile away up the stream, almost the highest exposure in the Beck, and about 300 to 400 yards away from the outcrop of the granite. How near it may be to the actual *contact* cannot be stated, because we do

	A.		*B.*	
Silica	58·55	per cent.	.....	61·05 per cent.
Alumina	17·13	,,	.....	17·95 ,,
Ferric Oxide ...	8·95	,,	.....	6·54 ,,
Lime	5·90	,,	.....	1·65 ,,
Magnesia	3·85	,,	.....	3·06 ,,
Potash...	3·44	,,	.....	5·33 ,,
Soda	1·56	,,	.....	2·55 ,,
Water	1·25	,,	.....	2·64 ,,
	100·63		.....	100·77

not know the contour of the granite underground; but it is certainly not very far away from it. The rock is here very completely "regenerated;" not a particle of *original* quartz remains, felspar is abundant, and there are many spots of various kinds.

It will be noted that *B* is unusually rich in alkali for a slate, though the figures can be closely paralleled by those of some other published analyses. So far as can be judged from the appearance of the rocks and their relationship to the line of strike, the two specimens represent the same slate.

There is nothing in the analyses, in spite of the increase of nearly 3 per cent. in the total alkalies, to justify any inference that a transfer of material has taken place from the granite to the slate. The balance of the accumulated evidence on this question appears to show that such transfer is either non-existent or very rare, except perhaps at the actual junction, and the above analyses are quite in harmony with this. Slates and shales are known to vary considerably in composition, within very moderate distances, in the same layers. *A* is much more calcareous and also more ferruginous than *B*, and this causes the main difference. It will also be noted that the proportion of potash to soda is almost identical in both cases, a fact which speaks strongly against the idea of the introduction of any alkali from an external source.

Concerning the question of newly-formed felspar in contact-slates, etc., it is to be remarked that more recent observations tend to show that its occurrence is not by any means so rare as was at one time supposed. This fact is emphasized by R. Beck, in a paper in which he records his own observation of felspar in the contact-rocks of the Elbe Valley (Tschermak's Min. and Petrog. Mittheilungen, p. 13, 1893), and refers to a list of other notices of similar occurrences. I may state that having myself of late very carefully examined specially prepared slides of a good number of contact-slates, etc., from various places on the Continent, I have found them to contain felspar in frequent instances, its occurrence not having been previously

recorded in published descriptions of the rocks from some of the localities. Thus, among others, notably the andalusite-hornfels of Andlau and neighbourhood is rich in felspar. Also the hornfels of Spitzenberg, in the Harz, the "Knotenglimmerschiefer" of Sauschwart, in the Erzgebirge, and several others, contain large amounts of newly-formed felspar. My own impression is that in most of the contact-mosaics of normal slates and slaty grits an examination of very thin sections, with adequate optical appliances, will show felspar to be present; that its occurrence at contacts is, in fact, rather the rule than the exception.[1]

The other point to which I wished to recur is that of the nature of the "spots" in the rock at Shap, and in contact-rocks generally.

The composition and origin of some of the "spots" and "knots" in contact-slates appear to me to be among the least understood of all the deeply interesting things concerned in the processes of contact-metamorphism. Their elucidation is surrounded with difficulties, but if they could be properly followed out and explained we should, I think, be a long way towards knowing what takes place when a rock is metamorphosed by an intruded granite, and what are some of the stages involved in bringing about the changes of which we are obliged to speak rather vaguely as re-crystallization, regeneration, molecular rearrangement, etc., etc.

That very little can be regarded as settled concerning the spots is evident from the very different descriptions and explanations, given by various observers, as to their nature and contents.

In some cases the spots (knoten) are stated to be imperfect crystals of definite minerals, or to consist of secondary products due to the decomposition of such minerals. Cordierite and andalusite, and their decomposition-products, are thus described as forming the spots, and we may add also white mica, and sometimes felspar, as playing the same part.

But it does not seem either necessary or desirable to speak of such definite mineral-occurrences under the general and vague name of "spots"; and, indeed, in those outer zones of contact-slates where the spots are most abundant and characteristic, these definite mineral grains or "imperfect crystals" are more usually absent, or only slightly represented.

Such large grains, or imperfect crystals, of definite minerals do occur in some parts of some contact-zones together with the more indefinite "spots" we are now considering, and as they are frequently

[1] In some contact-rocks the felspar is so developed that it is only a question of a glance through the microscope, even with low powers, to make sure of its presence in quantity and that it is a new formation. Thus, in some of the contact-slates and grits (greywackes) of the Elbe Valley and the Lausitz district of Saxony there are large grains of well-cleaved orthoclase and well-twinned plagioclase, whose enclosures of biotite, quartz, etc., place their nature as contact-minerals beyond question. It is in the limpid and often fine-grained "mosaic" of such rocks that the presence of felspar appears to have been often overlooked, and in which, nevertheless, I consider its presence can nearly always be demonstrated.

It may be of use to mention that a good series of specimens of the most interesting contact-rocks alluded to above, from Saxony, can be obtained from the mineral depôt at the Mining College at Freiberg.

marked off from the rest of the rock in much the same manner, when seen in ordinary light, there is some temptation to consider them as forming part of the same processes. But I think a full consideration of them shows the fallacy of this, and that they should be considered quite separately. Nor is it at all justifiable to speak of the more indefinite spots, such as I am about to describe, as composed of decomposition-products of a mineral, as *e.g.* cordierite, unless the connection and *transition* can be absolutely proved.

As a more general thing the spots and knots are spoken of as consisting of, or containing, "aggregations of pigment," "aggregations of iron-ores," or of "dark grains," or of "carbonaceous material," or they are described as consisting of the same materials as the rock in which they occur with less of some particular mineral, often biotite or white mica; or also as representing "less developed portions of the general mass."

I have made a careful study of the spots in the Shap rocks, and of many other occurrences, in the hope of obtaining a better understanding of them. It does not seem possible to arrive at any perfectly definite and general conclusion concerning them; but certain things appear to apply to many, and to allow of some slight inferences as to their possible nature, so that it may be worth while to record a few observations made on them. This can, perhaps, best be done by describing one or two particular cases first.

Thus a "Fruchtschiefer" from Tirpersdorf, in Saxony, consists mainly of white mica, mostly lying flat in the plane of cleavage, but also a good deal lying edgewise in various degrees. There is a little quartz-mosaic, a good deal of biotite, some of it in large individuals, lots of small tourmalines, zircons, etc. The whole is rich in dark grains and plates, many of which are transparent or translucent ilmenite. The numerous spots are about the size and shape of small grains of wheat, and do not seem to have any definite relationship to the rock-cleavage. Under low power, in ordinary light, they are sharply marked off from the surrounding material by being very much richer in dark grains and plates, and by having yellow colour. The boundary of this yellow colour is mostly quite sharp. Biotite occurs in the spots as small flakes, and larger individuals of it sometimes lie partly in them and partly outside.

In polarized light, again, the spots are marked off very sharply, being much darker than their surroundings, and containing much less vividly-polarizing mica, at the same time that the contrast is heightened by an extra accumulation of such mica as a frame immediately round them. At a thicker, central portion of the slide (which, however, must be a really thin one to make out anything distinctly) the spot is seen to contain a great deal of a mosaic of small grains or flakes, or both, which cannot be all identified, but some of which is mica and some probably quartz. It can be seen that these grains, etc., lie in, and are quite distinct from, the yellow substance which colours the spot and surrounds all its contents like a sort of groundmass. In nearly all these thicker spots one gets the impression that there is, among the other constituents, more or

less of isotropic matter, referable to the yellow substance, but it is not possible to make quite sure.

If other spots be examined which project out to the thinnest edges of the slide, and higher powers are used, the yellow substance is seen to be of a pale yellowish-green colour, free from any trace of dichroism, and full of an irregular network of exceedingly fine cracks or cleavages, only well seen with high powers and much lowered condenser or partly closed iris-diaphragm. In polarized light the grains and flakes of the contained minerals are again seen, and it is here possible to make sure that in among them are isotropic spaces. Some of these may be seen of such relatively large area,—so many times larger than any of the contained minerals,—that all idea of compensation by overlapping individuals is dispelled. One can satisfy oneself that what is seen consists of the yellow substance pure and simple, and that the portion examined has no action whatever on polarized light.

In addition to the appearances above described there are spots in the same slide where the yellow substance is deeper in colour, and polarizes faintly in the lowest possible grey tints. In some few cases this polarization becomes distinct enough to give a tolerably uniform, though fibrous or flaky, extinction over a good large area of the spot, the contained minerals being seen in among this with their own independent extinctions as usual. Under these conditions the yellow substance sometimes shows traces of dichroism. In this faintly dichroic and lowly polarizing form it more resembles, in its appearance in polarized light, some occurrences of serpentinous material than anything else to which I can compare it.

This same substance, varying in colour from much deeper yellow to almost colourless, and varying in its dichroism and its degree of bi-refraction, may be seen again in the spots of many other contact-rocks. Thus, in a "Knotenthonschiefer" from Andlauthal, in the Vosges, the spots again are marked off in ordinary and polarized light exactly as in the above descriptions. The yellow substance is present and of the same nature, but in the outer rims of the spots polarized light produces in it a very faintly-speckled, minutely-cryptocrystalline effect, while in the central portions it does not itself polarize but contains, as usual, a mosaic of grains, some of which are quartz, while a few may be made out as felspar, with mica. This minutely-speckled polarization is very frequent in this substance in rocks from many localities, and seems to correspond to the first stage of its passage from an amorphous to a more or less crystalline condition.

In some occurrences of "Knotenschiefer" this substance is limited to the spots, but there are others in which smaller portions of it occur more or less abundantly outside them, in among the general materials of the slates, as patches or streaks of various size. And in the more inner zones of contact, after the spots have ceased to appear, it is still often seen, usually in smaller amount but in some cases very abundantly.

(*To be continued.*)

Woodwardian Museum, Cambridge. Catalogue of the Fossils in the Students' Stratigraphical Series. By H. Woods, B.A., F.G.S. 8vo. pp. 23. (University Press, 1893.)

THERE is much to be said in favour of the plan, which has been carried out at Cambridge, and also in some of the principal University Museums in Germany, of forming for teaching purposes a separate series of fossils to illustrate the principal types which characterize the different stratigraphical horizons of the geological series. This catalogue, which has been very carefully drawn up by Mr. Woods, gives the generic and specific names, and the class and order of the common typical fossils occurring in each of the principal geological divisions in this country, ranging from the Lower Cambrian to the Barnwell and Barrington gravels and peat, which have been selected and arranged for the use of the students at Cambridge. Altogether the names of 558 species are given, of which 182 are from the Palæozoic, 290 from the Mesozoic, and 186 from the Tertiary rocks. As furnishing a highly useful key to the leading fossils in our British rocks, this catalogue has a practical value beyond the purpose for which it was designed. To allow of notes and additions it has been interleaved with blank pages.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—November 22nd, 1893.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "The Basic Eruptive Rocks of Gran." By W. C. Brögger, Ord. Prof. of Min. and Geol. at the University of Christiania, For. Memb. Geol. Soc.

In previous communications the author has maintained that the different masses of eruptive rock which occur within the sunken tract of country lying between Lake Mjösen and the Langesundsfjord are genetically connected, and have succeeded each other in a regular order. The oldest rocks are the most basic, the youngest (except the unimportant dykes of diabase) are the most acid, and between the two extremes he has found a continuous series.

He is now preparing a detailed monograph on this series of eruptive rocks, and in the present communication he gives an account of the results of his work on the oldest members.

Several bosses of basic plutonic rock, now forming a series of dome-shaped hills, lie along a north-and-south fissure-line. The most northerly is that of Brandberget in the parish of Gran, about 50 or 60 kilometres N.N.W. of Christiania, and the most southerly occurs at Dignaes on Lake Tyrifjord, about 35 kilom. W.N.W. of the same town. The prevailing rock in these bosses is a medium or coarse-grained olivine-gabbro-diabase; but pyroxenites, hornblendites, camptonites, labrador-porphyrites, and augite-diorites also occur. Analyses of the typical rocks from three localities on the north-and-south line are given, and the conclusion is reached that

the average basicity of the rocks forming different bosses decreases from north to south.

The contact-metamorphism is referred to; and the presence of hypersthene in the altered *Oggygia*-shales, coupled with its absence from the same shales where they have been affected by quartz-syenite, leads the author to the conclusion that the chemical nature of the intrusive rock does, in certain cases, produce an influence on the character of the metamorphism.

Innumerable dykes and sheets of camptonite and bostonite are associated with the above-mentioned plutonic bosses. These are regarded by the author as having been produced by differentiation from a magma having the composition of the average olivine-gabbro-diabase. Analyses are given, and it is proved that a mixture of nine parts of the average camptonite and two of the average bostonite would produce a magma having the composition of the average olivine-gabbro-diabase. The petrographical variations, such as the occurrence of pyroxenites and augite-diorites, in the plutonic masses themselves are described, and attributed to differentiation under physical conditions unlike those which gave rise to the camptonites and bostonites.

In discussing the general laws of differentiation the author points out that it must have taken place before crystallization to any extent had occurred, because there is a marked difference in mineralogical composition between the rocks occurring as bosses and those occurring as dykes; and, further, that it is dependent on the laws which determine the sequence of crystal-building, in so far as the compounds which, on given conditions, would first crystallize are those which have diffused to the cooling margin, and so produced a contact-stratum, of peculiar chemical composition, before any crystallization had taken place.

2. "On the Sequence of Perlitic and Spherulitic Structures (a Rejoinder to Criticism)." By Frank Rutley, Esq., F.G.S.

This paper relates to the order in which the perlitic and spherulitic structures have been developed in a felsitic lava of Ordovician age from Long Sleddale, Westmoreland. The author having described this rock in a paper, published in the Quarterly Journal of the Society in 1884, and the accuracy of the views then expressed having been questioned, now endeavours to confirm his original statements, adducing in support fresh observations made upon this and other rocks of a similar kind.

3. "Enclosures of Quartz in Lava of Stromboli, etc., and the Changes in Composition produced by them." By Prof. H. J. Johnston-Lavis, M.D., F.G.S.

The author describes the existence of enclosures of quartz in a lava-stream at the Punta Petrazza on the east side of Stromboli, and also in the rock of the neck of Strombolicchio. He describes the effects of the rocks upon the enclosures, concluding that the quartz has undergone fluxion but not fusion, and has supplied silica to the containing lavas, thus causing an increase in the amount of pyroxene and a diminution in the amount of magnetite in the

portions of those lavas that surround the inclusions and raising the percentage of silica. He suggests that such a process at greater depths and higher temperature may, under certain conditions, convert a basic rock into a more acid one, so that possibly the andesite of Strombolicchio may have been of basaltic character at an earlier period of its progress towards the surface. He offers the suggestion that other rocks or minerals once associated with the quartz have been assimilated by the magma.

CORRESPONDENCE.

LEVEL OF LAKE LEMAN.

SIR,—As Mr. Davison remarks, the level he quotes is not of reliable precision—not adequately mounted.

Would not the Pierre de Niton, in the Port of Geneva, be a more satisfactory bench mark to watch and compare with selected stations? Upon its position turns the whole of the Swiss Federal Survey.

Prof. Forel, who gives a full account of the results of levelling, does not say much as to the systems, all of which depended upon foreign (*i.e.* not Swiss) official surveys, so far as sea-level goes.

On the other hand, as compared with stations on Swiss ground, any variation of level ought to come out with certainty—and that is *the* point. I hope this interesting matter will not be lost sight of.

In Dufour's map the level of the Pierre de Niton figures as 376·64 metres. The later Siegfried map gives it as 376·86 metres, a difference of 22 centimetres. Is this evidence of altered level or of improved exactitude?

In times when the great Rhone ice-sheet was melting back from the plains, but not as yet so notably from the mountains, would not the disencumbered land westward rise more than at the east end of Lake Leman? See Osmond Fisher's "Physics of the Earth's Crust," second edition, page 327, note 2, for equations approximately to the point.

MARSHALL HALL.

EASTERTON, PARKSTONE, DORSET, 2*nd Nov.* 1893.

VOLCANIC SERIES IN THE MALVERN HILLS.

SIR,—The excavations for the new reservoir to the east of and below the Herefordshire Beacon have brought to light piecemeal an interesting series of beds. At no one time was there a complete exposure of them all; but as I have watched the progress of the work closely I have been able to make out with tolerable accuracy their general bearing.

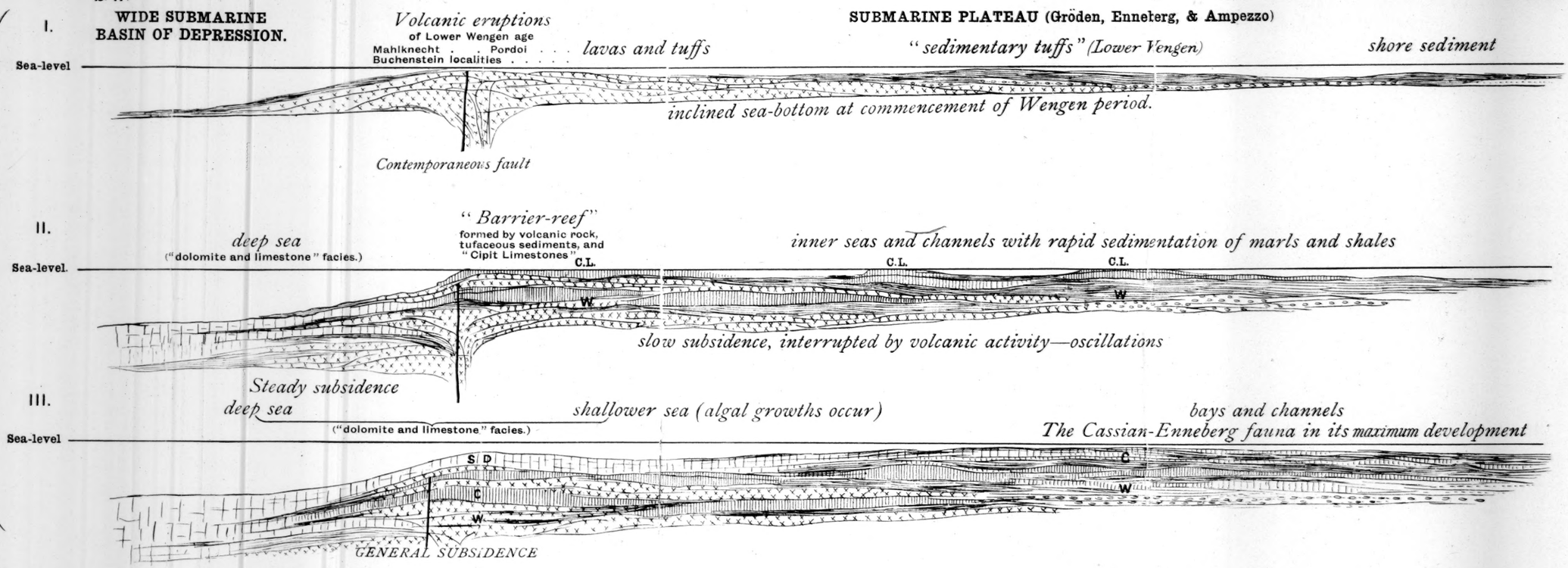
The strike is nearly due north and south at this particular spot, *i.e.* parallel to the axis of the Malvern Hills. The dip 40° East.

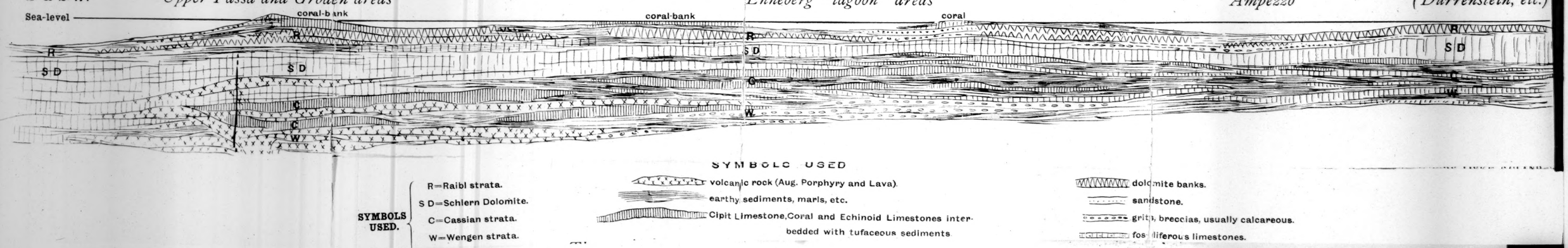
The beds are shown by the microscope to be (commencing from the East): obsidian or very fine ash, coarse ash, and some basic rock. Some of the slides correspond in a remarkable degree with others cut from rocks further south. I hope in time to be able to establish connection between them. The whole area, however, has been subjected to so much movement and shattering that the greatest care and patience will be necessary to unravel the problem.

GREAT MALVERN, *Oct.* 30*th*, 1893. HENRY DYKE ACLAND.

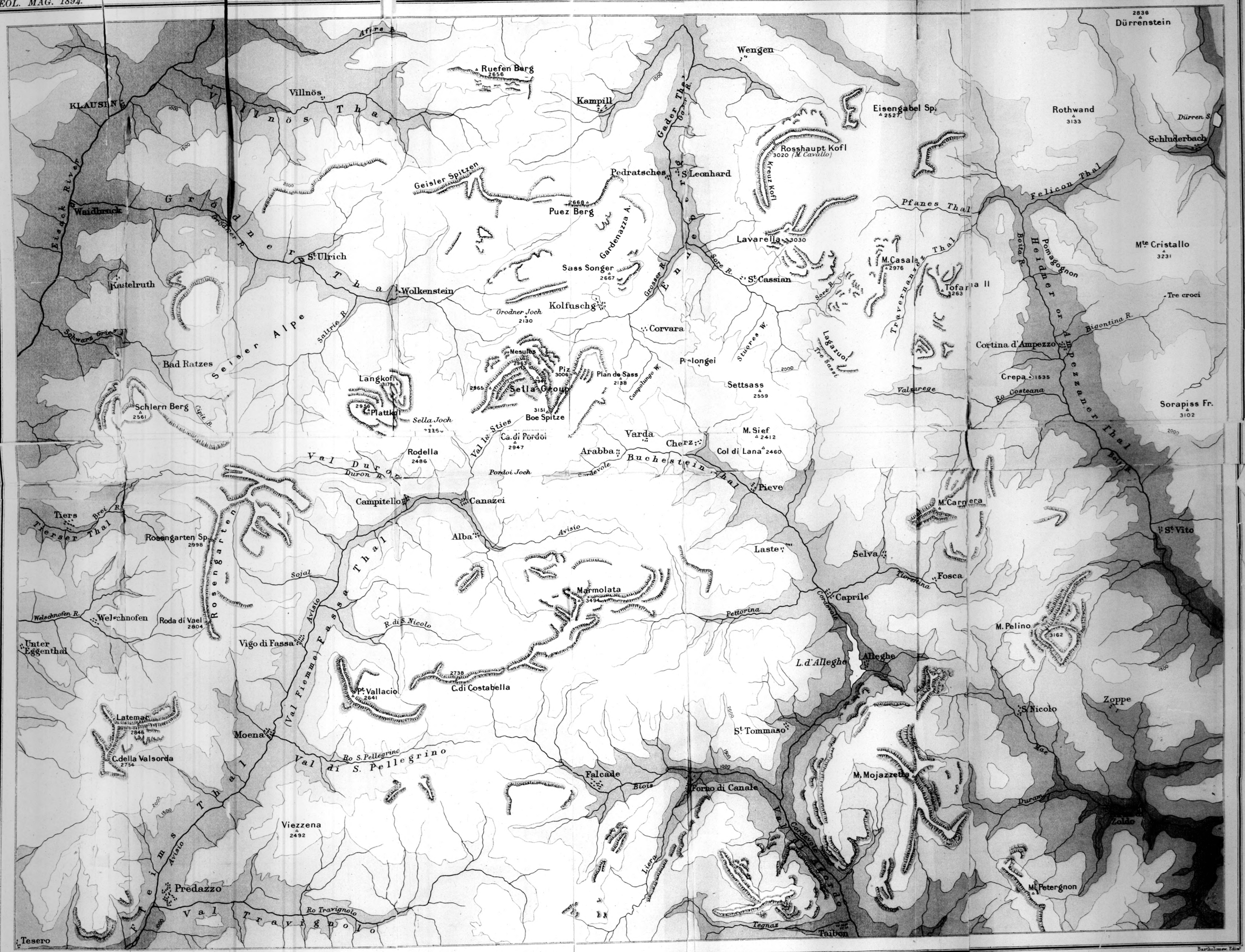
DIAGRAMS ILLUSTRATING "CORAL IN THE DOLOMITES OF SOUTH TYROL," BY MISS MARIA M. OGILVIE, D.Sc.

Progressive Stages of the WENGEN AND CASSIAN HETEROPIC DEPOSITS in South Tyrol during "positive" movement





MAP OF THE GRÖDEN, ENNEBERG, AMPEZZO, AND UPPER FASSA VALLEYS.



British Statute Miles 69·16 = 1 Degree

Kilometres 111·3 = 1 Degree

The Map is contoured at Heights of 1000 - 1500 and 2000 Metres.

The Edinburgh Geographical Institute

Bartholomew, Edin.